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UK Greenhouse Gas Inventory, 1990 to 2011

Annual Report for Submission under the Framework Convention on Climate Change

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Preface

This is the United Kingdom's National Inventory Report (NIR) submitted in April 2013 to the United Nations Framework Convention on Climate Change (UNFCCC). It contains national greenhouse gas emission estimates for the period 1990-2011, and the descriptions of the methods used to produce the estimates. The report is prepared in accordance with decision 18/CP.8[1] and follows the structure outlined in the *Annotated outline of the National Inventory Report including reporting elements under the Kyoto Protocol*[2]. This submission constitutes the UK's submission under the Kyoto Protocol. A Compact Disk on the inside of the back flap of this report contains tabular data in the Common Reporting Format (CRF) covering the United Kingdom's greenhouse gas emissions for the same period.

The greenhouse gas inventory (GHGI) is based on the same datasets used by the UK in the National Atmospheric Emissions Inventory (NAEI) for reporting atmospheric emissions under other international agreements. The GHGI is therefore consistent with the NAEI where they overlap.

The greenhouse gas inventory is compiled on behalf of the UK Department of Energy and Climate Change (DECC) Science Division, by Ricardo-AEA. We acknowledge the positive support and advice from DECC throughout the work, and we are grateful for the help of all those who have contributed to this NIR. A list of the contributors can be found in **Chapter 18**.

The GHGI is compiled according to IPCC 1996 Revised Guidelines and Good Practice Guidance (IPCC, 1997; 2000 and 2003), with reference to the new 2006 IPCC Guidelines (IPCC, 2006). Each year the inventory is updated to include the latest data available. Improvements to the methodology are backdated as necessary to ensure a consistent time series. Methodological changes are made to take account of new data sources, or new guidance from IPCC, relevant work by CORINAIR, and new research, sponsored by DECC or otherwise.

[1] FCCC Decision 18/CP.8. Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, part I:UNFCCC reporting guidelines on annual inventories. Report of the Conference of the Parties on its Eighth Session, held at New Delhi from 23 October to 1 November 2002. FCCC/CP/2002/7/Add.2 28 March 2003.

[2] http://unfccc.int/files/national_reports/annex_i_ghg_inventories/reporting_requirements/application/pdf/annotated_nir_outline.pdf

Units and Conversions

Emissions of greenhouse gases presented in this report are normally given in Gigagrammes (Gg), Million tonnes (Mt) and Teragrammes (Tg). GWP weighted emissions are also provided. To convert between the units of emissions, use the conversion factors given below.

Prefixes and multiplication factors

Multiplication factor	Abbreviation	Prefix	Symbol
1,000,000,000,000,000	10^{15}	peta	P
1,000,000,000,000	10^{12}	tera	T
1,000,000,000	10^{9}	giga	G
1,000,000	10^{6}	mega	M
1,000	10^{3}	kilo	k
100	10^{2}	hecto	h
10	10^{1}	deca	da
0.1	10^{-1}	deci	d
0.01	10^{-2}	centi	c
0.001	10^{-3}	milli	m
0.000,001	10^{-6}	micro	μ

1 kilotonne (kt) = 10^3 tonnes = 1,000 tonnes
1 Mega tonne (Mt) = 10^6 tonnes = 1,000,000 tonnes

1 Gigagramme (Gg) = 1 kt
1 Teragramme (Tg) = 1 Mt

Conversion of carbon emitted to carbon dioxide emitted

To covert emissions expressed in weight of carbon, to emissions in weight of carbon dioxide, multiply by 44/12.

Conversion of Gg of greenhouse gas emitted into Gg CO_2 equivalent

Gg (of GHG) * GWP = Gg CO_2 equivalent.

The GWP is the Global Warming Potential of the greenhouse gas. The GWPs of greenhouse gases used in this report are given in **Table 1.1 of Chapter 1**.

Abbreviations for Greenhouse Gases and Chemical Compounds

Type of greenhouse gas	Formula or abbreviation	Name
Direct	CH_4	Methane
Direct	CO_2	Carbon dioxide
Direct	N_2O	Nitrous oxide
Direct	HFCs	Hydrofluorocarbons
Direct	PFCs	Perfluorocarbons
Direct	SF_6	Sulphur hexafluoride
Indirect	CO	Carbon monoxide
Indirect	NMVOC	Non-methane volatile organic compound
Indirect	NO_X	Nitrogen oxides (reported as nitrogen dioxide)
Indirect	SO_2	Sulphur oxides (reported as sulphur dioxide)

HFCs, PFCs and SF_6 are collectively known as the 'F-gases'.

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Document Revision History

Issue	Revision History
Issue – Draft	Reviewed by DECC
Issue 1	Submitted to the EUMM on March 15th 2013
Issue 2	Submitted to the UNFCCC on April 15th 2013
Issue 3	Prepared for printing and the NAEI website May 2013

ES.1 BACKGROUND INFORMATION ON GREENHOUSE GAS INVENTORIES, CLIMATE CHANGE AND SUPPLEMENTARY INFORMATION REQUIRED UNDER ARTICLE 7, PARAGRAPH 1, OF THE KYOTO PROTOCOL

ES.1.1 Background information on climate change (e.g. as it pertains to the national context)

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) was esatblished in 1997 in response to the threat of dangerous climate change. Under this Protocol, the UK agreed to an emissions reduction target of -12.5% on 1990 levels, to be achieved during the first commitment period of the Protocol, which runs from 2008 to 2012.

The UK ***Climate Change Act,*** which became part of UK law in November 2008, subsequently introduced a new, more ambitious and legally binding target for the UK to reduce GHG emissions to 80% below base year levels by 2050. This will be done by way of legally binding five year *Carbon Budgets*. In May 2009, the UK Government set the levels of the first three five-year carbon budgets, covering the periods 2008-12, 2013-17 and 2018-22. The fourth carbon budget, covering the period 2023-27, was set in June 2011. In December 2011, the UK's *Carbon Plan*, which sets out plans for achieving the first four carbon budgets, superseded the UK's *Low Carbon Transition Plan*, which was published in July 2009. The *Annual statement of emissions,* published by 31st March each year, reports to the UK Parliament on progress towards these Carbon Budgets. The fourth *Annual Statement*, in relation to the 2011 reporting year, was published in March 2013.

Further information on the UK's action to tackle climate change can be found at:

www.gov.uk/government/organisations/department-of-energy-climate-change
https://www.gov.uk/government/organisations/department-for-environment-food-rural-affairs

ES.1.2 Background information on greenhouse gas inventories

The UK ratified the United Nations Framework Convention on Climate Change (UNFCCC) in December 1993, and the Convention came into force in March 1994. Parties to the Convention are committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs).

This is the UK's National Inventory Report (NIR) submitted in April 2013. It contains GHG emissions estimates for the period 1990 to 2011, and describes the methodology on which the estimates are based. This report and the attached Common Reporting Format (CRF) have been compiled in accordance with UNFCCC reporting guidelines on annual inventories contained in document FCCC/CP/2002/8 and follows the structure outlined in the *Annotated*

outline of the National Inventory Report including reporting elements under the Kyoto Protocol[3]

The UK Greenhouse Gas Inventory is compiled and maintained by a consortium led by Ricardo-AEA – the **Inventory Agency** - under contract to the UK Department of Energy and Climate Change (DECC). Ricardo-AEA is directly responsible for producing the emissions estimates for CRF categories Energy (CRF sector 1), Industrial Processes (CRF sector 2), Solvent and Other Product Use (CRF sector 3), and Waste (CRF Sector 6). Ricardo-AEA is also responsible for inventory planning, data collection, QA/QC and inventory management and archiving. Aether, a partner within the consortium, is responsible for compiling emissions from railways and for the UK's Overseas Territories (OTs) and Crown Dependencies (CDs), and for reviewing, updating and making improvements to the QA/QC procedures that are in place.

Agricultural sector emissions (CRF sector 4) are produced by Rothamsted Research, under contract to the UK Department for Environment, Food and Rural Affairs (Defra). Land Use, Land-Use Change and Forestry emissions (CRF sector 5) are calculated by the UK Centre for Ecology and Hydrology (CEH), under separate contract to DECC.

DECC, Defra and the Devolved Administrations also fund research contracts to provide improved emissions estimates for certain sources such as fluorinated gases, landfill methane, enteric fermentation and shipping.

The inventory covers the six direct greenhouse gases under the Kyoto Protocol. These are as follows:

- Carbon dioxide (CO_2);
- Methane (CH_4);
- Nitrous oxide (N_2O);
- Hydrofluorocarbons (HFCs) ;
- Perfluorocarbons (PFCs) ; and
- Sulphur hexafluoride (SF_6).

These gases contribute directly to climate change owing to their positive radiative forcing effect. Also reported are four indirect greenhouse gases:

- Nitrogen oxides (reported as NO_2);
- Carbon monoxide;
- Non-Methane Volatile Organic Compounds (NMVOC); and
- Sulphur oxides (reported as SO_2).

The structure of this report is as follows:

- Chapter 1 of the report provides an introduction and background information on greenhouse gas inventories.
- Chapter 2 provides a summary of the emission trends for aggregated greenhouse gas emissions by source and gas.
- Chapters 3 to 9 discuss each of the main source categories in detail.

[3] http://unfccc.int/files/national_reports/annex_i_ghg_inventories/reporting_requirements/application/pdf/annotated_nir_outline.pdf

- Chapter 10 presents information on recalculations, improvements and a summary of responses to review processes.
- Chapter 11 deals with KP-LULUCF reporting
- Chapter 12 contains information on accounting of Kyoto units
- Chapters 13 and 14 contain information regarding changes to the National System and the National Registry
- Chapter 15 contains information on the minimisation of adverse impacts in accordance with Article 3, paragraph 14.

There are also Annexes to provide key source analysis and other detailed information as set out in the IPCC Guidance and Guidelines.

Unless otherwise indicated, percentage contributions and changes quoted refer to net emissions (i.e. emissions minus removals), based on the full coverage of UK emissions including all relevant Overseas Territories and Crown Dependencies, consistent with the UK's submission to the UNFCCC.

The UK inventory provides data to assess progress with the UK's commitments under the Kyoto Protocol, the UK's contribution to the EU's targets under the Kyoto Protocol and also progress towards the UK Government's own Carbon Budgets. Geographical coverage for these three purposes differs to some extent, because of the following:

1. The UK Government Carbon Budgets apply to the UK only, and exclude all emissions from the UK's Crown Dependencies and Overseas Territories;
2. The Kyoto commitment extends coverage to the UK's Crown Dependencies (Guernsey, Jersey and the Isle of Man) and Overseas Territories that have ratified the Kyoto Protocol (the Cayman Islands, the Falkland Islands, Bermuda, Montserrat and Gibraltar);
3. The UK's commitments under the EU Monitoring Mechanism, which has been set up to enable the EU to monitor progress against its Kyoto Protocol target, only includes the UK and Gibraltar, since the Crown Dependencies and other Overseas Territories are not part of the EU.

Emissions data for Coverage 1 are reported here for information and to facilitate comparison between different publications. Coverage 2 is used for the data in the CRF tables submitted to the UNFCCC. Coverage 3 is used for the data in the CRF tables submitted under the EUMM Tables ES2.1 to ES3.1 show CO_2 and the direct greenhouse gases, disaggregated by gas and by sector for geographical Coverage 2. Tables ES3.2 and ES3.3 show emissions for the Kyoto basket based on Coverage 2 and 3, respectively.

Table ES4 has data on indirect greenhouse gas emissions, for geographical coverage 2.

ES.1.3 Background information on supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol.

Background information on supplementary information required under Article 7, Paragraph 1 of the Kyoto Protocol is presented in **Chapter 1, Section 1.1.3**.

ES.2 SUMMARY OF NATIONAL EMISSION AND REMOVAL RELATED TRENDS, AND EMISSIONS AND REMOVALS FROM KP-LULUCF ACTIVITIES

ES.2.1 GHG Inventory

Table ES2.1: Emissions of GHGs in terms of carbon dioxide equivalent emissions including all estimated GHG emissions from the Crown Dependencies and relevant Overseas Territories, 1990-2011. (Mt CO_2 Equivalent)

Table ES1	Mt CO_2 Equivalent																						% change
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	1990 - 2011
CO_2 (Including net LULUCF)	593.5	600.7	583.5	568.8	562.5	555.3	576.4	551.8	556.0	546.6	554.8	566.0	549.3	559.4	560.1	556.1	554.8	545.8	533.2	482.7	499.9	460.7	-22%
CO_2 (Excluding net LULUCF)	590.4	597.4	581.0	567.3	561.3	552.9	574.8	550.3	555.4	546.4	555.2	566.9	551.1	561.5	563.3	559.5	558.5	549.9	537.7	487.2	504.2	464.6	-21%
CH_4 (Including net LULUCF)	99.2	98.3	96.6	93.3	86.0	85.2	83.0	78.5	74.3	69.3	65.0	59.3	56.3	52.3	50.7	48.5	47.5	46.4	45.0	43.7	43.0	42.1	-58%
CH_4 (Excluding net LULUCF)	99.1	98.3	96.5	93.3	85.9	85.2	83.0	78.5	74.2	69.2	65.0	59.3	56.2	52.2	50.6	48.5	47.5	46.3	45.0	43.7	43.0	42.0	-58%
N_2O (Including net LULUCF)	68.3	68.5	63.7	59.0	59.5	58.0	57.8	58.1	57.9	47.4	46.5	43.8	42.0	41.6	42.1	41.2	39.1	38.4	37.4	35.3	35.9	34.8	-49%
N_2O (Excluding net LULUCF)	67.4	67.6	62.8	58.1	58.6	57.2	57.0	57.3	57.1	46.5	45.7	43.0	41.2	40.8	41.4	40.5	38.4	37.7	36.7	34.7	35.3	34.2	-49%
HFCs	11.4	11.9	12.3	13.0	13.9	15.3	16.6	19.0	16.9	10.3	9.3	10.3	10.7	11.9	11.2	12.1	12.8	13.1	13.7	14.0	14.4	14.7	29%
PFCs	1.4	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.2	0.3	-77%
SF_6	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.8	1.4	1.5	1.3	1.1	1.1	0.9	0.8	0.7	0.7	0.7	0.6	-41%
Total (Emissions including net GHG from LULUCF)	774.8	781.6	757.7	735.8	723.6	715.6	735.6	709.1	706.7	675.3	677.9	681.2	660.1	666.7	665.6	659.3	655.4	644.7	630.2	576.6	594.1	553.1	-29%
Total (Emissions excluding net GHG from LULUCF)	770.8	777.5	754.4	733.4	721.4	712.3	733.0	706.6	705.2	674.2	677.5	681.3	661.1	668.0	668.0	661.9	658.3	648.0	634.0	580.4	597.8	556.5	-28%

1. One Mt equals one Tg, which is 10^{12} g (1,000,000,000,000 g) or one million tonnes
2. Net Emissions are reported in the Common Reporting Format
3. Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

Table ES2.1 presents the UK Greenhouse Gas Inventory totals by gas, including and excluding net emissions from LULUCF. The largest contribution to total emissions is CO_2, which contributed 83% to total net emissions in 2011. Methane emissions account for the next largest share (8%), and N_2O emissions make up a further 6%. Emissions of all of these gases have decreased since 1990, contributing to an overall decrease of 29%.

ES.2.2 KP-LULUCF activities

KP-LULUCF activities relate to estimated emissions and removals from:

- **Article 3.3**, the net emissions or removals of Afforestation, Reforestation and Deforestation (ARD) since 1990;
- **Article 3.4**, the net flux due to forest management since 1990 (the UK has elected forest management from the choices of: cropland management, grassland management, forest management and revegetation); and
- **Article 3.7**, emissions in 1990 only from deforestation, added to the base year for Kyoto reporting (only applicable for countries where there is a net LULUCF emission in 1990, which is the case for the UK).

Table **ES2.2** details the emissions and removals from these activities which are included in the UK's emissions total for reporting under the Kyoto Protocol.

Table ES 2.2 KP-LULUCF activities (Mt CO_2e)

	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Article 3.3		0.3	0.4	0.5	0.4	0.2	0.0	-0.2	-0.4	-0.7	-0.8	-0.8
Article 3.4 (capped at -0.37 MtC)		-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
Article 3.7	0.3											

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Article 3.3	-1.0	-1.1	-1.2	-1.4	-1.5	-1.9	-2.0	-2.1	-2.1	-2.4	-2.5
Article 3.4 (capped at -0.37 MtC)	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4
Article 3.7											

ES.3 OVERVIEW OF SOURCE AND SINK CATEGORY EMISSION ESTIMATES AND TRENDS, INCLUDING KP-LULUCF ACTIVITIES

ES.3.1 GHG Inventory

Table ES3.1 details total net emissions of GHGs, aggregated by IPCC sector.

Table ES3.1 Aggregated emission trends per source category, including all estimated GHG emissions from the Crown Dependencies and selected relevant Overseas Territories (Mt CO_2 equivalent).

Table ES3.1	Aggregated emission trends per source category (Mt CO_2 equivalent)																					
Source Category	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
1. Energy	610.8	620.4	604.1	588.6	575.1	567.4	587.0	561.5	564.3	553.4	560.7	572.2	555.9	564.2	565.1	559.6	558.4	548.1	536.2	489.5	505.4	466.0
2. Industrial Processes	54.4	52.6	47.2	43.9	46.4	46.6	48.4	50.6	49.0	32.2	31.8	30.5	28.7	30.5	30.9	31.3	30.7	32.3	31.5	26.1	27.6	26.5
3. Solvents and Other Product Use[a]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4. Agriculture	58.2	57.9	57.7	57.1	57.3	56.9	57.1	57.2	56.6	56.0	54.1	51.1	51.2	50.8	50.9	50.5	49.1	47.8	47.0	46.2	46.7	46.7
5. LULUCF	4.0	4.1	3.4	2.3	2.1	3.3	2.6	2.4	1.5	1.0	0.4	-0.1	-1.0	-1.3	-2.4	-2.6	-3.0	-3.3	-3.8	-3.8	-3.7	-3.3
6. Waste	47.5	46.6	45.3	43.9	42.7	41.5	40.4	37.3	35.3	32.6	30.9	27.5	25.4	22.5	21.0	20.5	20.1	19.8	19.3	18.5	18.0	17.4
Total (net emissions)	**774.8**	**781.6**	**757.7**	**735.8**	**723.6**	**715.6**	**735.6**	**709.1**	**706.7**	**675.3**	**677.9**	**681.2**	**660.1**	**666.7**	**665.6**	**659.3**	**655.4**	**644.7**	**630.2**	**576.6**	**594.1**	**553.1**

Footnotes:

[a] Solvents and other product use emissions occur as NMVOC and so do not appear in this Table which covers direct greenhouse gases

Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

The largest contribution to greenhouse gas emissions is from the energy sector. In 2011 this contributed 84% to the total emissions. Emissions of CO_2, CH_4 and N_2O all arise from this sector. Since 1990, emissions from the energy sector have declined by about 24%.

The second largest source of greenhouse gases is the agricultural sector. Emissions from this sector arise for both CH_4 and N_2O. Since 1990, emissions from this sector have declined by 20%, due to a decline in emissions from enteric fermentation and agricultural waste disposal (largely related to lower livestock numbers) and from agricultural soils (largely related to changes in agricultural practices, and a decline in the use of synthetic fertiliser).

Industrial processes make up the third largest source of greenhouse gases in the UK, contributing 5% to the national total in 2011. Emissions of all six direct greenhouse gases occur from this sector.

Land Use, Land-use Change and Forestry contains sinks as well as sources of CO_2 emissions. LULUCF was a net sink in 2011. Emissions from this source occur for CO_2, N_2O and CH_4.

The remaining source that contributes to direct greenhouse gas totals is waste. In 2011 this contributed around 3% to the national total. This sector leads to emissions of CO_2, CH_4 and N_2O, with emissions occurring from waste incineration, solid waste disposal on land and wastewater handling. Emissions from this sector have steadily declined and in 2011 were 63% below 1990 levels.

Total net emissions have decreased by 29% since 1990.

ES.3.2 KP Basket and KP-LULUCF Activities

ES.3.2 provides the time series of the UK Kyoto basket of emissions (UNFCCC geographical coverage), and ES.3.3 presents the equivalent values for the EU coverage of the UK inventory. The tables show the emissions making up the base year and subsequent years, and also estimated emissions and removals from KP-LULUCF activities.

The Base Year for emissions of carbon dioxide, methane and nitrous oxide is 1990. The Base Year for emissions of fluorinated gases (F-gases) is 1995.

The tables include two Base Year totals. The first (in the Kyoto Protocol Total row) is the 'Base Year' calculated from the 2011 inventory, based on the totals calculated for each sector this year, together with Article 3.7, and including any recalculations made since the previous inventory. The 'Fixed Base Year' is the base year total calculated from the 2004 Inventory, which has been used to calculate the UK's Assigned Amount, and in table ES.3.3, the UK's contribution to the EU's Assigned Amount. This has been reviewed during an In Country Review of the UK inventory in March 2007 and agreed by the UNFCCC. This is the total that the UK's progress towards its Kyoto Protocol target will be judged against.

Table ES3.2 Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2011 (in Mt CO_2 equivalent) – UNFCCC Coverage.

Table ES3.2	Mt CO_2 Equivalent																							% Changes	
	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	1990-2011	Base Year - 2011
CO_2	590.4	590.4	597.4	581.0	567.3	561.3	552.9	574.8	550.3	555.4	546.4	555.2	566.9	551.1	561.5	563.3	559.5	558.5	549.9	537.7	487.2	504.2	464.6	-21%	-21%
CH_4	99.1	99.1	98.3	96.5	93.3	85.9	85.2	83.0	78.5	74.2	69.2	65.0	59.3	56.2	52.2	50.6	48.5	47.5	46.3	45.0	43.7	43.0	42.0	-58%	-58%
N_2O	67.4	67.4	67.6	62.8	58.1	58.6	57.2	57.0	57.3	57.1	46.5	45.7	43.0	41.2	40.8	41.4	40.5	38.4	37.7	36.7	34.7	35.3	34.2	-49%	-49%
HFCs	15.3	11.4	11.9	12.3	13.0	13.9	15.3	16.6	19.0	16.9	10.3	9.3	10.3	10.7	11.9	11.2	12.1	12.8	13.1	13.7	14.0	14.4	14.7	29%	-4%
PFCs	0.5	1.4	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.2	0.3	-77%	-30%
SF_6	1.2	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.8	1.4	1.5	1.3	1.1	1.1	0.9	0.8	0.7	0.7	0.7	0.6	-41%	-51%
Grand Total	774.0	770.8	777.5	754.4	733.4	721.4	712.3	733.0	706.6	705.2	674.2	677.5	681.3	661.1	668.0	668.0	661.9	658.3	648.0	634.0	580.4	597.8	556.5	-28%	-28%
Article 3.3		0.3	0.4	0.5	0.4	0.2	0.0	-0.2	-0.4	-0.7	-0.8	-0.8	-1.0	-1.1	-1.2	-1.4	-1.5	-1.9	-2.0	-2.1	-2.1	-2.4	-2.5		
Article 3.4 (capped at -0.37 MtC)		-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4		
Article 3.7	0.3																								
Kyoto Protocol Total	774.3	769.7	776.5	753.4	732.4	720.3	711.0	731.4	704.8	703.1	672.0	675.2	678.9	658.6	665.5	665.2	659.0	655.0	644.7	630.5	576.8	594.0	552.6	-28%	-29%
Fixed Base Year	779.9																								-29%

Footnotes:

[1] The Fixed Base Year is taken from the UK's Assigned Amount report. This report was submitted in 2006, based on emissions reported in the 1990-2004 Greenhouse Gas Inventory, and was subject to an official review in 2007, which concluded that this figure was correct. This base year is now fixed, and is the value that the UK will be assessed against for its Kyoto Protocol target.

Emissions and removals associated with LULUCF enter the table only through the rows labelled Article 3.3, Article 3.4 and Article 3.7. The UK has chosen to account only for forest management under Article 3.4 during the first commitment period.

Geographical coverage of this table includes the Crown Dependencies Jersey, Guernsey and the Isle of Man, and the Overseas Territories which have joined the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. These are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar.

Table ES3.3 Kyoto basket of emissions, and emissions associated with Articles 3.3, 3.4 and 3.7, 1990-2011 (in Mt CO_2 equivalent) – EUMM Coverage.

Table ES3.3	Mt CO_2 Equivalent																							% Changes	
	Base Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	1990-2011	Base Year - 2011
CO_2	587.6	587.6	594.6	578.2	564.5	558.4	550.0	571.7	547.2	552.0	543.3	552.1	564.0	548.0	558.6	560.2	556.3	555.2	546.4	534.4	484.0	500.9	461.3	-21%	-21%
CH_4	98.6	98.6	97.8	96.0	92.8	85.5	84.7	82.5	78.0	73.7	68.8	64.6	58.9	55.8	51.9	50.3	48.1	47.1	46.0	44.6	43.4	42.7	41.7	-58%	-58%
N_2O	67.3	67.3	67.5	62.7	58.0	58.5	57.0	56.8	57.1	56.9	46.4	45.5	42.9	41.1	40.7	41.3	40.4	38.3	37.6	36.6	34.6	35.2	34.1	-49%	-49%
HFCs	15.3	11.4	11.9	12.3	13.0	13.9	15.3	16.5	19.0	16.9	10.2	9.3	10.2	10.6	11.8	11.1	12.0	12.7	13.0	13.5	13.9	14.2	14.5	27%	-5%
PFCs	0.5	1.4	1.2	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.2	0.3	-77%	-30%
SF_6	1.2	1.0	1.1	1.1	1.2	1.2	1.2	1.3	1.2	1.3	1.4	1.8	1.4	1.5	1.3	1.1	1.1	0.9	0.8	0.7	0.7	0.7	0.6	-41%	-51%
Grand Total	770.5	767.3	774.0	750.9	730.0	717.9	708.8	729.3	702.9	701.2	670.4	673.8	677.7	657.4	664.5	664.4	658.2	654.4	643.9	630.1	576.6	593.9	552.6	-28%	-28%
Article 3.3		0.3	0.4	0.5	0.4	0.2	0.0	-0.2	-0.4	-0.7	-0.8	-0.8	-1.0	-1.1	-1.2	-1.4	-1.5	-1.9	-2.0	-2.1	-2.1	-2.4	-2.5		
Article 3.4 (capped at -0.37 MtC)		-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4	-1.4		
Article 3.7	0.3																								
Kyoto Protocol Total	770.8	766.2	773.1	750.0	729.0	716.8	707.4	727.7	701.1	699.1	668.2	671.5	675.3	654.9	662.0	661.6	655.3	651.1	640.5	626.6	573.1	590.1	548.7	-28%	-23%
Fixed Base Year	776.3																								-29%

Footnotes:

[1] The Fixed Base Year was supplied to the EU to calculate the Assigned Amount for the EU.

Emissions and removals associated with LULUCF enter the table only through the rows labelled Article 3.3, Article 3.4 and Article 3.7. The UK has chosen to account only for forest management under Article 3.4.

Geographical coverage of this table includes the UK and Gibraltar only.

ES.4 OTHER INFORMATION

ES.4 lists the indirect greenhouse gases for which the UK has made emissions estimates. Nitrogen oxides, carbon monoxide and NMVOCs are included in the inventory because they can produce increases in tropospheric ozone concentrations and this increases radiative forcing. Sulphur oxides are included because they contribute to aerosol formation.

Table ES4.1 Emissions of Indirect Greenhouse Gases in the UK, 1990-2011 (in kt).

Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
NO_x	2,879	2,770	2,706	2,537	2,426	2,307	2,201	2,028	1,971	1,854	1,783
CO	9,129	9,335	8,915	8,575	8,113	7,611	7,652	7,610	6,835	6,474	5,697
NMVOC	2,700	2,634	2,554	2,433	2,347	2,163	2,083	1,976	1,819	1,634	1,498
SO_2	3,724	3,563	3,483	3,142	2,681	2,373	2,028	1,667	1,648	1,262	1,242

Gas	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
NO_x	1,746	1,672	1,649	1,591	1,576	1,524	1,459	1,319	1,148	1,110	1,037
CO	5,350	4,769	4,379	3,972	3,578	3,360	3,063	2,856	2,392	2,250	2,159
NMVOC	1,413	1,328	1,208	1,122	1,050	1,003	974	887	800	772	753
SO_2	1,141	1,022	999	837	705	655	572	493	399	410	382

Footnotes:
Geographical coverage of the emissions in the table includes emissions from the Crown Dependencies and Overseas Territories

Since 1990, emissions of all indirect gases have decreased. The largest source of emissions for all the indirect gases is the energy sector. For NO_x, CO and SO_2, over 90% of emissions arise from activities within this sector. For NMVOC, 32% of emissions are energy related, with other significant contributions from both the industrial processes and solvent sectors.

Contacts

This work is part of the Climate, Energy, Science and Analysis (CESA) Research Programme of the Department for Energy and Climate Change. The Land Use Change and Forestry estimates were provided by the Centre for Ecology and Hydrology (CEH) Edinburgh (Contract CPEG 1). Rothamsted Research provide the estimates of agricultural emissions.

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A copy of this report and related data may be found on the website maintained by Ricardo-AEA for DECC: http://ghgi.decc.gov.uk/

1 Introduction

This is the UK's 2013 National Inventory Report (NIR). From 2010 onwards, the NIR contains new information required for reporting under the Kyoto Protocol as required by decision 15/CMP.1[4].

The National Inventory Report (NIR), as established by decision 18/CP.8[5], is one element of the annual greenhouse gas (GHG) inventory that is required to be submitted to the UNFCCC by Annex I Parties to the Convention on 15th April of each year. The other elements of this submission include the reporting of GHG emissions by sources and removals by sinks in the Common Reporting Format (CRF) tables, and any other additional information in support of this submission.

The UK is an Annex I Party to the Convention and is also a Party to the Kyoto Protocol. This means the UK is required to report supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol[6], with the inventory submission due under the Convention, in accordance with paragraph 3(a) of decision 15/CMP.1. This NIR contains this supplementary information in the appropriate sections.

1.1 BACKGROUND INFORMATION ON GREENHOUSE GAS INVENTORIES, AND CLIMATE CHANGE

1.1.1 Background information on Climate Change

Countries that have signed and ratified the Kyoto Protocol are legally bound to reduce their greenhouse gas emissions by an agreed amount. A single European Union Kyoto Protocol reduction target for greenhouse gas emissions of -8% compared to base-year levels was negotiated, and a Burden Sharing Agreement allocates the target between Member States of the European Union. Under this agreement, the UK reduction target is -12.5% on base-year levels. The UK needs to achieve this reduction during the first commitment period of the Kyoto Protocol which runs from 2008 to 2012.

The Climate Change Act[7] became UK Law on the 26th November 2008. This legislation introduced a new, more ambitious and legally binding target for the UK to reduce GHG emissions to 80% below base year by 2050, with legally binding five year GHG budgets. The independent Committee on Climate Change (CCC) was set up to advise the UK Government on the scope and level of UK carbon budgets.

[4] 15/CMP.1 Guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol. http://unfccc.int/resource/docs/2005/cmp1/eng/08a02.pdf#page=54

[5] 18/CP.8 Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, part I: UNFCCC reporting guidelines on annual inventories. FCCC/CP/2002/7/Add.2 28 March 2003. http://unfccc.int/resource/docs/cop8/07a02.pdf

[6] Kyoto Protocol to the United Nations Framework Convention on Climate Change. http://unfccc.int/resource/docs/convkp/kpeng.pdf

[7] Climate Change Act 2008. http://www.legislation.gov.uk/ukpga/2008/27/contents

Further information on the UK's action to tackle climate change can be found on the following Government Department websites:

www.gov.uk/government/organisations/department-of-energy-climate-change
https://www.gov.uk/government/policies/adapting-to-climate-change

1.1.2 Background information on Greenhouse Gas Inventories

1.1.2.1 Reporting of the UK Greenhouse Gas Inventory

The UK ratified the UNFCCC in December 1993 and the Convention came into force in March 1994. Parties to the Convention are committed to develop, publish and regularly update national emission inventories of greenhouse gases (GHGs).

The UK's National Inventory Report (NIR) is prepared in accordance with decision 18/CP.8 and follows the structure outlined in the document FCCC/SBSTA/2006/9[8]. In addition, the UK also reports GHG emissions by sources and removals by sinks in the Common Reporting Format (CRF) tables. The estimates are consistent with the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997a, b, c), Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000) and the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC, 2003).

The UK Greenhouse Gas Inventory is compiled and maintained by a consortium led by Ricardo-AEA – the **Inventory Agency** - under contract to the Science Division in the UK Department of Energy and Climate Change (DECC). Full details of the institutional arrangements for the preparation of the GHG inventory are explained in **Section 1.2.1**.

This report and corresponding CRF tables provide annual emission estimates submitted by the UK to the UNFCCC for the period 1990 to 2011. To fulfil both European Union Monitoring Mechanism (EUMM)[9] and UNFCCC reporting requirements the UK has prepared two sets of CRF tables and has officially reported both sets. These two sets of tables present emission estimates for different geographical coverages:

1. **EUMM CRF (reported 15th January):** Includes UK, and Gibraltar
2. **UNFCCC CRF (reported 15th April):** Includes UK, Crown Dependencies (Jersey, Guernsey, Isle of Man) and the Overseas Territories (Bermuda, Cayman Islands, Montserrat, Falkland Islands, Gibraltar).

The main part of the report presents GHG emissions for the years 1990-2011, and discusses the reasons for the trends and any changes in the estimates due to revisions made since the last inventory. The Annexes provide supplementary detail of the methodology of the estimates, include sections on the estimation of uncertainties and atmospheric verification of the inventory, and explain how the greenhouse gas inventory relates to the IPCC Guidelines and the National Atmospheric Emissions Inventory (NAEI). They contain mappings between IPCC, NAEI source categories and fuel types as well as emission factors and references to the technical literature. The IPCC Good Practice Guidance (IPCC, 2000) requires that certain sets of activity data are reported as well as the Common Reporting Format (CRF) Tables. These datasets are included on a CD ROM attached to this report.

8 Updated UNFCCC reporting guidelines on annual inventories following incorporation of the provisions of decision 14/CP.11. http://unfccc.int/resource/docs/2006/sbsta/eng/09.pdf

9 European Union mechanism for monitoring and reporting greenhouse gas emissions http://ec.europa.eu/clima/policies/g-gas/monitoring/index_en.htm

The CRF consists of a series of detailed spreadsheets, with one set for each year. The CRF reports much more detail than the IPCC Sectoral Tables, in that it contains additional tables of activity data as well as updated versions of the IPCC Sectoral Tables. A copy of the CRF for each reported geographical coverage accompanies this report on a CD ROM.

1.1.2.2 Geographical coverage of UK emissions

The UK compiles and reports two different sets of CRF tables, each with a different geographical coverage of emissions to fulfil the reporting requirements of both the EUMM and the UNFCCC.

A major source of activity data for the UK inventory is provided by DECC through the publication of the Digest of UK Energy Statistics (DUKES) (see **Table 1-6**). The geographical coverage of the statistics is the United Kingdom (DECC, 2012). Shipments to the Channel Islands and the Isle of Man from the United Kingdom are not classed as exports, and supplies of solid fuel and petroleum to these islands are therefore included as part of the United Kingdom inland consumption or deliveries.

The definition of the UK used by DECC accords with that of the "economic territory of the United Kingdom" used by the UK Office for National Statistics, which in turn accords with the definition required to be used under the European System of Accounts (ESA95).

The geographical coverage of the UK inventory presented in this NIR has been extended to include emissions from territories associated with the UK, who have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol:

- **Crown Dependencies (CDs)**
  The Crown Dependencies are the Isle of Man and the Channel Islands (Jersey and Guernsey). They are not part of the United Kingdom, and are largely self-governing with their own legislative assemblies and systems of law. The British Government, however, is responsible for their defence and international relations. The Crown Dependencies are not members of the European Union.

- **Overseas Territories (OTs)**, formerly called Dependent Territories
  The Overseas Territories are the Cayman Islands, Falkland Islands, Bermuda, Montserrat and Gibraltar. They are constitutionally not part of the United Kingdom. They have separate constitutions, and most Overseas Territories have elected governments with varying degrees of responsibilities for domestic matters. The Governor, who is appointed by, and represents, Her Majesty the Queen, retains responsibility for external affairs, internal security, defence, and in most cases the public service. The OTs include the Sovereign Bases (SBs) as a subset.

1.1.2.3 Greenhouse Gases Reported in the UK Inventory

The greenhouse gases reported are:

Direct greenhouse gases

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulphur hexafluoride (SF_6)

Indirect greenhouse gases

- Nitrogen oxides (NO_x, as NO_2)
- Carbon monoxide (CO)
- Non-Methane Volatile Organic Compounds (NMVOC)
- Sulphur dioxide (SO_2)

These indirect gases have indirect effects on radiative forcing and are requested by the UNFCCC guidelines.

Emissions estimates are made using methodologies corresponding mostly to the detailed sectoral Tier 2 or Tier 3 methods in the IPCC Guidelines.

Most sources are reported in the detail required by the CRF. The main exceptions are the emissions of individual halocarbon species, which cannot always be reported individually because some of these are considered commercially sensitive data. Consequently, emissions data have been aggregated to protect this information. It is however possible to report the total Global Warming Potential (GWP) of these gases and hence the total global warming potential of all UK greenhouse gases.

1.1.2.4 Global Warming Potentials of the Greenhouse Gases

The direct greenhouse gases have different effectiveness in radiative forcing. The GWP is a means of providing a simple measure of the relative radiative effects of the emissions of the various gases. The index is defined as the cumulative radiative forcing between the present and a future time horizon caused by a unit mass of gas emitted now, expressed relative to that of CO_2. It is necessary to define a time horizon because the gases have different lifetimes in the atmosphere. **Table 1-1** shows GWPs defined on a 100-year horizon (IPCC, 1996). These are the GWP values required by FCCC/CP/2002/8, consistent with Decision 2/CP.3[10].

Table 1-1 GWP of Greenhouse Gases on a 100-Year Horizon used in the UK NIR

Gas	GWP
Carbon dioxide	1
Methane	21
Nitrous oxide	310
HFCs	140-11,700
HFC-23	11,700
HFC-32	650
HFC-125	2,800
HFC-134	1,000
HFC-134a	1,300
HFC-143a	3,800
HFC-152a	140
HFC-227ea	2,900
HFC-236fa	6,300
HFC-43-10mee	1,300
PFCs	6,500-9,200

[10] 2/CP.3 Methodological issues related to the Kyoto Protocol http://unfccc.int/resource/docs/cop3/07a01.pdf

Gas	GWP
PFC-14	6,500
PFC-116	9,200
PFC-218	7,000
PFC-318	8,700
PFC-3-1-10	7,000
PFC-5-1-14	7,400
SF_6	23,900

A range of GWP values is shown for HFCs and PFCs because these refer to a number of species, each with its own GWP. By weighting the emission of a gas with its GWP it is possible to estimate the total contribution to global warming of UK greenhouse gas emissions.

GWPs of certain greenhouse gases have been updated in the IPCC Third and Fourth Assessment Reports (IPCC, 2001; IPCC, 2007). However, it has been agreed internationally that these will not apply to the Kyoto targets under the first commitment period. All calculations and inventory submissions throughout this period will be based on the GWPs given in the Second Assessment Report (IPCC, 1996).

1.1.3 Background information on supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

Information relating to the supplementary information required under Article 7, Paragraph 1 of the Kyoto Protocol can be found in the relevant sections of this report.

Table 1-2 below summarises the background information relating to the supplementary information and provides cross-references to appropriate parts of the report where more detailed information is provided.

Table 1-2 Background information on supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol

Reporting element	Background information
Supplementary inventory information for activities under Article 3, Paragraphs 3 and 4	The reporting of KP-LULUCF is carried out by the Centre for Ecology and Hydrology (CEH) on behalf of DECC. The UK has chosen to elect Forest Management (FM) as an activity under Article 3.4. The calculations follow the same method and use the same models as the UNFCCC estimates for LULUCF, which are also prepared by CEH. Further information can be found in **Chapter 11**.
Information on Kyoto Protocol units	The UK National Registry is operated and maintained by the Environment Agency on behalf of DECC. Information on accounting of Kyoto Protocol units, including a summary of information reported in the standard electronic format (SEF) tables is provided in **Chapter 12**. SEF tables including information for the period 01.01.2011 to 31.12.2011 can be found in **Annex 6** of this report.
Changes in National Systems	The UK National System is managed and maintained by DECC, who is the Single National Entity. Changes to the national System are reported in **Chapter 13** of this report.

Reporting element	Background information
Changes in National Registry	The EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway have decided to operate their registries in a consolidated manner. The Consolidated System of EU registries was certified on 1 June 2012 and went to production on 20 June 2012. The UK National Registry is operated and maintained by the Environment Agency on behalf of DECC. The National Registry is represented on the National Inventory Steering Committee. All changes in the National Registry are reported in **Chapter 14**.
Minimisation of adverse impacts in accordance with Article 3, Paragraph 14	The UK has undertaken several assessments, reviews and analysis projects to better understand the impacts its policies could have on developing countries, and how they could be addressed. We have supported several knowledge transfer, research collaboration and capacity building. Further details on the UK's efforts to minimise adverse impacts is provided in **Chapter 15**.

1.2 INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

1.2.1 Institutional, legal and procedural arrangements for compiling the UK inventory

The UK greenhouse gas inventory is compiled and maintained by a consortium led by Ricardo-AEA – the **Inventory Agency** - under contract to the Science Division in the UK Department of Energy and Climate Change (DECC). Ricardo-AEA is responsible for producing the emissions estimates for CRF categories Energy (CRF sector 1), Industrial Processes (CRF sector 2), Solvent and Other Product Use (CRF sector 3), and Waste (CRF Sector 6). Ricardo-AEA is also responsible for inventory planning, data collection, QA/QC and inventory management and archiving. Aether, a partner within the consortium, is responsible for compiling emissions from railways and for the OTs and CDs, and for reviewing, updating and making improvements to the QA/QC procedures that are in place.

Agricultural sector emissions (CRF sector 4) are produced by Rothamsted Research, under contract to Defra. Land Use, Land-Use Change and Forestry emissions (CRF sector 5) are calculated by the UK Natural Environment Research Council's Centre for Ecology and Hydrology (CEH), under separate contract to the Science Division (DECC). The KP-LULUCF information is also produced by CEH. The mechanism for generating the KP-LULUCF data and the quality control and assurance procedures applied are an integral part of the UK's National System.

1.2.1.1 The UK Greenhouse Gas National Inventory System (UK NIS)

The Marrakesh Accords of the Kyoto Protocol (Decision 20/CP.7[11]) define the requirements for National Inventory Systems (NIS), including the need to establish legal, procedural and institutional arrangements to ensure that all parties to the Protocol estimate and report their GHG emissions in accordance with relevant decisions of the COP, facilitate UNFCCC Reviews and improve the quality of their inventories. Under related EU legislation set out in

[11] 20/CP.7 Guidelines for national systems under Article 5, paragraph 1, of the Kyoto Protocol http://unfccc.int/resource/docs/cop7/13a03.pdf

Decision 280/2004/EC[12] the UK was required to have in place its NIS by 31st December 2005. The development of more formal agreements between DECC and Key Data Providers (KDPs) within the NIS is on-going and is specifying the framework of data supply, such as data quality, format, timeliness and security to underpin the GHG inventory.

Figure 1-1 summarises the key organisational structure of the UK NIS and **Section 1.2.2** includes further detailed information on the roles and responsibilities of each of the key organisations.

Figure 1-1 Key organisational structure of the UK National Inventory System

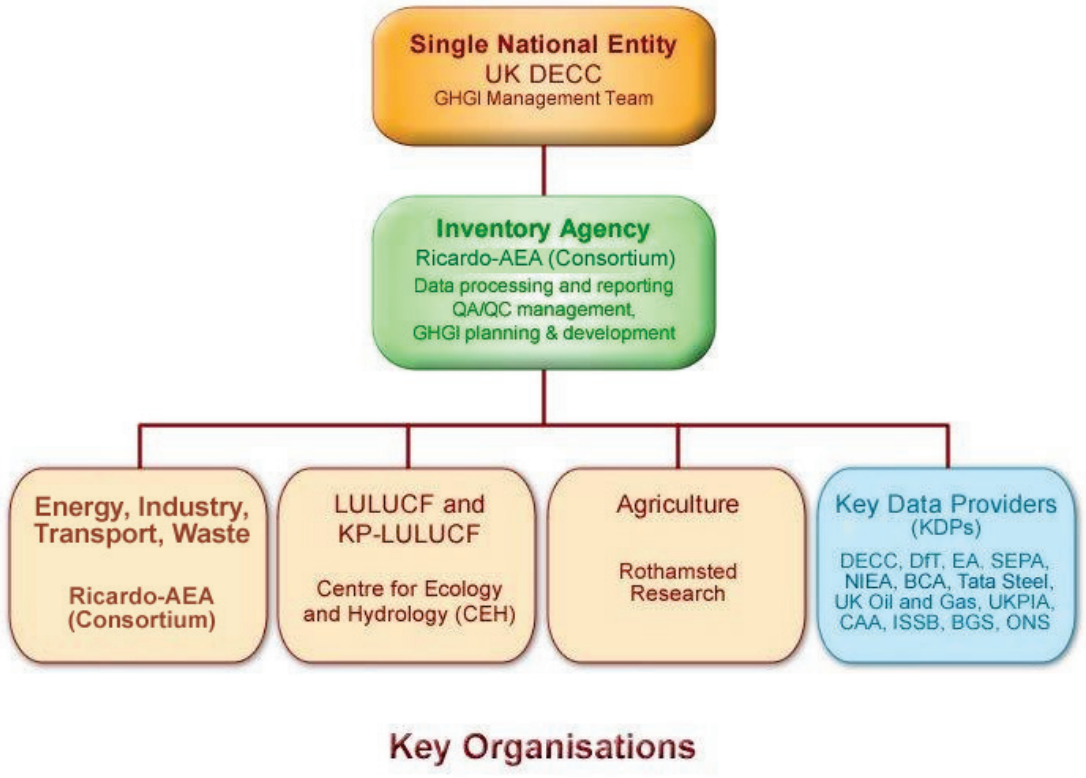
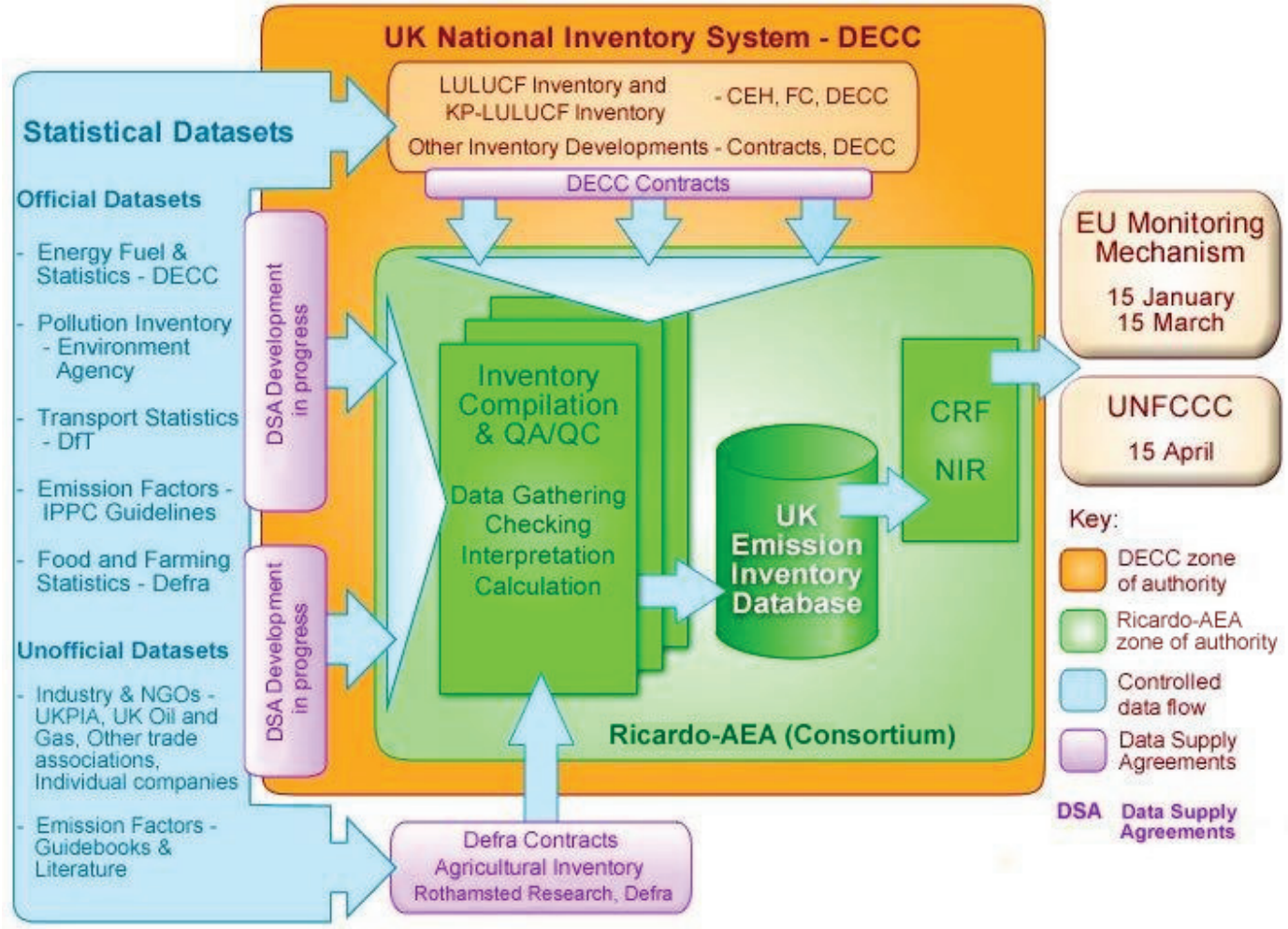


Figure 1-2 shows the main elements the UK National Inventory System, including provision of data to the European Union under the terms of the EU Monitoring Mechanism. DECC is the **Single National Entity** responsible for submitting the UK's greenhouse gas inventory (GHGI) to the UNFCCC. Ricardo-AEA, in collaboration with Aether and other partners compiles the GHGI on behalf of DECC, and produces disaggregated estimates for the Devolved Administrations within the UK.

Key Data Providers include other Government Departments such as Department for Environment, Food and Rural Affairs (Defra) and Department for Transport (DfT), Non-Departmental Public Bodies such as the Environment Agency for England and Wales (EA), Northern Ireland Environment Agency (NIEA) and the Scottish Environment Protection Agency (SEPA), private companies such as Tata Steel, BP Chemicals, and business organisations such as the UK Petroleum Industry Association (UKPIA) and the Mineral Products Association (MPA).

[12] Decision No 280/2004/EC of the European Parliament and of the Council of 11 February 2004 concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:049:0001:0001:EN:PDF

Figure 1-2 Main elements for the preparation of the UK greenhouse gas inventory



1.2.1.2 Legal Framework

The UK GHGI has been reported annually since 1994, and historically the acquisition of the data required has been based on a combination of existing environmental and energy legislation and informal arrangements with industry contacts and trade associations.

The legislation relied upon has been set up for other purposes, such as:

- Integrated Pollution Prevention and Control (IPPC) regulations (industrial point source emission data from UK environmental regulatory agencies); and,
- Statistics of Trade Act (UK energy statistics from DECC).

To meet the standards required under the Kyoto Protocol, the UK introduced new legislation specifically for national inventory purposes which took effect from November 2005[13]. This legislation makes provision for DECC's Secretary of State to issue a notice in the event that information required for the inventory that has been sought voluntarily is not provided. The UK values voluntary participation and this legislation is intended as a last resort once all other avenues to elicit the required data, in the format and to the timing specified, have failed. The legislation includes penalties for failure to comply, and authority for entry to premises to obtain information required or verify information provided.

To ensure that the system works most effectively and to minimise the need for legislative action, DECC is currently setting up data supply agreements (DSAs) with relevant organisations to build upon existing relationships with data supply organisations. These agreements formalise the acquisition of data and clarify the main requirements of quality, format, security and timely delivery of data for the national inventory. This process is on-going, through the National Inventory Steering Committee which is a forum of inventory stakeholders that DECC chairs (see **Section 1.2.2.4** below).

There are currently three DSAs in place, with SEPA, NIEA and DfT.

1.2.2 Overview of Inventory Planning

As summarised in **Section 1.2.1**, the UK has designated authorities with clear roles and responsibilities. The following sections summarise the roles and responsibilities of key stakeholders in the UK NIS.

1.2.2.1 Single National Entity – DECC

Since its creation in October 2008, the UK Government Department of Energy and Climate Change (DECC) has been appointed as the Single National Entity for the UK and this has been confirmed in writing to the UN Executive Secretary. DECC has overall responsibility for the UK Greenhouse Gas Inventory and the UK National System and carries out this function on behalf of Her Majesty's Government and the Devolved Administrations (Wales, Scotland and Northern Ireland). DECC is responsible for the institutional, legal and procedural arrangements for the national system and for the strategic development of the national inventory.

Within DECC, the Science Division administers this responsibility. The Science Division coordinates expertise from across Government and manages research contracts to ensure that the UK Greenhouse Gas Inventory meets international standards set out in the UNFCCC

[13] Greenhouse Gas Emissions Trading Scheme (Amendment) and National Emissions Inventory Regulations 2005 http://www.opsi.gov.uk/si/si2005/20052903.htm

reporting guidelines, the Kyoto Protocol and the IPCC 1996 Guidelines and IPCC Good Practice Guidance.

As the designated Single National Entity for the UK GHG NIS, DECC has the following roles and responsibilities:

National Inventory System management and planning

- Overall control of the NIS development and function;
- Management of contracts and delivery of GHG inventory; and
- Definition of performance criteria for NIS key organisations.

Development of legal and contractual infrastructure

- Review of legal and organisational structure; and
- Implementation of legal instruments and contractual developments as required to meet guidelines.

The contact point for the single national entity is provided on the **Contacts** page of the NIR.

1.2.2.2 Inventory Agency – Ricardo-AEA Consortium

A new 3-year contract was established for the Inventory Agency in late 2011 following a competitive tendering exercise. Ricardo-AEA leads the consortium responsible for compiling the inventory, under contract to DECC. Ricardo-AEA is responsible for all aspects of national inventory preparation, reporting and quality management. The consortium consists of:

- Ricardo-AEA – lead contractor;
- Aether – responsible for estimates from railways and the Overseas Territories (OTs) and Crown Dependencies (CDs), and for improvements to the QA/QC plan;
- SKM Enviros – contribute to the F-gas inventory, in future inventory submissions;
- CEH[14] and AMEC – part of the consortium, but with no direct input to the GHG inventory.

Ricardo-AEA together with the project partners prepares the national atmospheric emissions inventory (NAEI) which is the core air emissions database from which the greenhouse gas inventory (GHGI) is extracted to ensure consistency in reporting across all air emissions for different reporting purposes (UNFCCC, UNECE etc.). Activities include: collecting and processing data from a wide range of sources; selecting appropriate emission factors and estimation methods according to IPCC guidance; compiling the inventory; managing all aspects of inventory QA/QC including QC of raw and processed data and data management tools, documentation and archiving, prioritisation of methodology and data improvements; carrying out uncertainty assessments; delivering the NIR (including CRF tables) by deadlines set to the EU Monitoring Mechanism (EUMM) and the UNFCCC on behalf of DECC; and, assisting with Article 8 reviews under the Kyoto Protocol.

As the designated Inventory Agency for the UK GHG National Inventory System, Ricardo-AEA has the following roles and responsibilities:

[14] The role of CEH under the inventory contract led by Ricardo-AEA is separate to the compilation of the LULUCF inventory, which CEH carry out under contract directly to DECC.

Planning

- Co-ordination with DECC to deliver the NIS;
- Review of current NIS performance and assessment of required development action; and
- Scheduling of tasks and responsibilities to deliver GHG inventory and NIS.

Preparation

- Drafting of agreements with key data providers; and
- Review of source data and identification of developments required to improve GHG inventory data quality.

Management

- Documentation and archiving;
- Dissemination of information regarding NIS to Key Data Providers; and
- Management of inventory QA/QC plans, programmes and activities.

Inventory compilation

- Data acquisition, processing and reporting; and
- Delivery of NIR (including associated CRF tables) to time and quality.

The inventory agency has formal systems in place to ensure that staff working on the inventory are well trained and able to carry out their duties effectively and efficiently. The technical competence of the staff is facilitated through a combination of the formal Ricardo-AEA and inventory-specific staff management and training systems. Roles and responsibilities for all inventory team members are clearly defined, and a comprehensive system of QA/QC is in place. **Section 1.6** sets out the QA/QC plan in detail. Ricardo-AEA systems ensure subcontractors are managed actively and deliver inputs to the inventory on time and to the specified quality.

The contact point for the inventory agency is provided on the **Contacts** page of the NIR.

CEH, under contract to DECC, is responsible for the preparation and development of the LULUCF inventory, including both emissions and removals of GHGs. CEH conduct specific research in the LULUCF sector and provide finalised data to Ricardo-AEA for inclusion within the UK GHG inventory.

Rothamsted Research (formerly North Wyke), under contract to Defra, is responsible for the preparation and development of the agriculture inventory. Rothamsted Research conducts specific research in the agriculture sector and provides finalised GHG emissions data to Ricardo-AEA for inclusion within the UK GHG inventory.

1.2.2.3 Key Data Providers and Reference Sources

The organisations that provide the raw data to the UK GHGI include a wide range of Government Departments, non-Departmental public bodies and Government Agencies, private companies and industrial trade associations.

Within the UK GHG National Inventory System, organisations that are Key Data Providers have the following roles and responsibilities:

Data quality, Format, Timeliness, Security

- Delivery of source data in the appropriate format and in time for inventory compilation, allowing for completion of required QA/QC procedures;
- Assessment of their data acquisition, processing and reporting systems, having regard for QA/QC requirements;
- Identification of any required organisational or legal development and resources to meet more stringent NIS data requirements, notably the security of data provision in the future; and,
- Communication with DECC, Ricardo-AEA and their peers or members to help to disseminate information regarding the GHG inventory and National System.

Energy statistics required for compilation of the GHGI are obtained from the Digest of UK Energy Statistics (DUKES). DUKES is compiled and published annually by a team of energy statisticians within DECC.

Information on industrial processes is provided either directly to Ricardo-AEA by the individual plant operators or from:

- The Environment Agency's Pollution Inventory for England and Wales;
- The Scottish Environment Protection Agency's European Pollution Emissions Register;
- The Northern Ireland Environment Agency's Inventory of Statutory Releases; and
- EU Emissions Trading Scheme installations which report emissions to the Environment Agency.

Reporting to these UK inventories for the purposes of environmental regulation is a statutory requirement for industries covered by Integrated Pollution Prevention and Control (IPPC). The data from these inventory sources is also used to quality check data provided voluntarily by companies directly to Ricardo-AEA.

Rothamsted Research compiles the inventory for agricultural emissions using agricultural statistics from Defra.

The UK Natural Environment Research Council's Centre for Ecology and Hydrology (CEH) compiles estimates of emissions and removals from LULUCF using land-use data and information on forestry from the Forestry Commission (a non-departmental public body), Government Departments and from other sources.

1.2.2.4 The National Inventory Steering Committee, pre-Submission Review and Approval of the UK GHGI

To meet the detailed requirements of a National System and to ensure the UK efficiently and effectively works towards implementing best practices, in 2006 DECC established a formal cross-Government body, the National Inventory Steering Committee (NISC), which is tasked with the official consideration and approval of the national inventory prior to submission to the UNFCCC. This pre-submission review is achieved at a NISC meeting prior to the finalisation of the inventory, and any recalculations to the inventory are presented and discussed at this meeting.

One of the main roles of the committee is to assist the DECC GHG inventory management team to manage and to prioritise the over-arching inventory QA and facilitate review and

improvement and better communication between inventory stakeholders across Government Departments and Agencies.

Special Advisors to the Steering Committee include the Inventory Agency team at Ricardo-AEA, other contractors, plus appropriate sector, legal and economic experts. These experts are responsible for reviewing methodologies, activity data, emission factors and emission estimates at a sectoral level and report their findings and recommendations to the steering committee on a regular basis. The committee is responsible for ensuring that the inventory meets international standards of quality, accuracy and completeness, and is delivered on time each year to the EU Monitoring Mechanism and the UNFCCC. The NISC is responsible for agreeing the priorities for the UK GHGI improvement programme. Where inventory improvement research is commissioned by the NISC, the research reports are reviewed and approved for use within the UK GHGI compilation by members of the NISC, managed by DECC, as part of the pre-submission review process.

Table 1-3 and **Table 1-4** below shows the main organisations engaged in the UK national inventory steering committee, and their roles and responsibilities in relation to the preparation and development of the national inventory. These tables include organisations from the following categories, many of which are classed as key data providers:

- Government Departments;
- Government Agencies (e.g. environmental regulators);
- Industry bodies or associations; and
- Consultants.

The development of the inventory is driven through the NISC, which meets twice a year to discuss the outcomes of recent peer, internal and expert reviews and to agree the prioritisation, funding, implementation and review of items on the UK inventory improvement programme. The Key Category Analysis and the uncertainty analysis, qualitative analysis from inventory agency experts as well as recommendations from reviews of the UK GHG inventory are used as guidance to help the members of the NISC make decisions on which improvements are the most important. Key categories with high uncertainty are given priority over non-key categories or categories with a low uncertainty. The annual inventory review feedback from the UNFCCC and European Union Monitoring Mechanism (EUMM), as well as sector-specific peer- or bilateral review findings are also considered to guide decisions on UK GHGI improvement priorities.

Following a UN Expert Review Team recommendation, a qualitative uncertainty analysis of the inventory is now being implemented by the inventory agency. This qualitative uncertainty analysis supports the Key Category Analysis and helps determine the highest priority emission sources in the UK where methodological improvements could be applied to improve the accuracy of emission estimates, or more detailed reporting used to improve transparency. This qualitative assessment is conducted by experts of the inventory team within the inventory cycle, including through a post-submission review of data sources, methods and feedback from the EUMM and UNFCCC ERTs.

In Spring each year, DECC and the inventory agency hold a review meeting, at which the findings of the EU and UN reviews, internal post-submission review and qualitative analysis of source categories are discussed in order to develop a comprehensive list of inventory improvement items for discussion, prioritisation and implementation via the NISC. This process ensures that sources that may not be determined as Key Source Categories are

identified as priorities for improvement, where that source may be particularly significant in terms of level or trend in the UK inventory.

Table 1-3 UK GHG National Inventory Steering Committee composition and responsibilities

Organisation	Role in relation to NISC	Key NISC responsibilities
DECC - Science Division	• GHG inventory manager • Manager of GHG research contracts • DECC annual climate change statistics and indicators	• Administer functions of Single National Entity for the UK National Inventory System • Overall responsibility for inventory development, compilation and reporting • Manage GHG inventory research contracts • Act as NISC Chair • Ensure that UK GHGI conforms to EU and UN international standards and requirements
Defra – Atmosphere and Local Environment (ALE)	• AQ inventory manager • Manager of AQ research contracts	• Ensure that UK AQ inventory conforms to EU and UN international standards and requirements • Overall responsibility for AQ inventory development, compilation and reporting
Defra	• Liaison between Defra and NISC	• Provide an analytical overview of all relevant Defra sectors • Provide link with Defra climate change mitigation team
DECC – National Climate Change	• UK Climate Change Programme • Climate Change Act • Carbon budgets	• Inform NISC of UK programme developments • Explore links between inventory and carbon budgets and potential requirements for either area
DECC – National Climate Change, Carbon Markets	• EU ETS • EU ETS Registry • EC Effort Sharing Decision	• Provide EU ETS fuel use and fuel characterisation datasets for determining industrial fuel use statistics and GHG emission from combustion sources • Provide updates of developments on the Effort Sharing Decision and EU ETS and any implications for future reporting requirements • Improve links between EU ETS registry and GHG inventory

Organisation	Role in relation to NISC	Key NISC responsibilities
DECC – International Climate Change (ICC)	• International negotiations • EUMM • UNFCCC	• Feed international emissions inventory expectations back to the NISC to ensure the UK complies and develops the inventory accordingly • Provide information on future international developments and changes to expectations • Provide advice on the implications of domestic changes to the inventory in an international arena
DECC – Science Division	• LULUCF Inventory manager	• Provide LULUCF inventory data that conforms to EU and UNFCCC international standards and requirements • Work with the NISC to ensure highest quality data
Defra – Farming and Food Science	• Agriculture Inventory Manager	• Providing agriculture inventory data that conforms to EU and UN international standards and requirements • Work with the NISC to ensure highest quality data
Defra – Water policy	• Waste water	• To provide water policy expertise to the inventory • To assist in improving waste water data quality
Defra – Waste	• Waste	• To provide waste policy expertise to the inventory, including landfill waste • To assist in improving landfill waste data quality
DECC – Energy Statistics (DUKES)	• Energy statistics	• Annual publication of Digest of UK Energy Statistics (DUKES) • Providing energy statistics to inform the UK inventory

Organisation	Role in relation to NISC	Key NISC responsibilities
Regulators: • Environment Agency for England and Wales • Scottish Environment Protection Agency • Northern Ireland Environment Agency	• Pollution inventory • EU ETS Registry	• Management, compilation, QA/QC and reporting of pollutant emission inventories/registers under IPCC regulations, and EU ETS annual emission reporting • Ensure that the pollutant emission inventories for industrial processes regulated under IPC/IPCC (PI, SPRI, ISR) are presented in the required format and timescale for inventory estimation and reporting • Collate information in annual emission reports for EU ETS
DECC oil and gas – Offshore Regulator	• Offshore oil and gas	• Providing offshore oil and gas industry annual activity and emission data to inform the UK inventory • Regulation of the offshore oil and gas industry, including management of the EEMS reporting system of environmental emissions from that sector
Department for Communities and Local Government (CLG)	• Housing statistics • Local Government issues	• Publication of housing statistics each year; coordination of technical requirements of local authorities to assist in action on climate change • Providing housing statistics to inform the UK inventory
Department for Transport (DfT)	• Transport	• Publication of transport statistics each year • Providing transport statistics to inform the UK inventory
Devolved Administrations	• Inventories for Devolved Administrations	• General review function for completeness and accuracy of inventory from a devolved perspective • Review aspects of the UK GHG inventory that correspond to devolved issues, ensuring the integration of local datasets and specific research where appropriate.

Organisation	Role in relation to NISC	Key NISC responsibilities
GHG inventory contractor (Ricardo-AEA)	• UK greenhouse gas inventory compilation and development	• Contractor responsible for the UK GHG inventory; activity data, methods, emission factors, emissions estimation, reporting and archiving • Deliver annual NIR and CRF submission to the UN and EU • Participate in sectoral expert panels as required
GHG inventory project partners (Aether)	• Inputs to greenhouse gas inventory compilation and development	• Contractor responsible for emissions from railways, and from Overseas Territories and Crown Dependencies • Joint role in managing the inventory improvement programme and development of QA/QC procedures
Agricultural inventory contractor (Rothamsted)	• Agriculture Inventory compilation and development	• Contractor responsible for agriculture inventory; activity data, methods, emission factors and emission estimation • Prepare and develop agriculture inventory and deliver on time for incorporation into national inventory • Participate in sectoral expert panels as required
LULUCF inventory contractor (CEH)	• LULUCF inventory	• Contractor responsible for LULUCF inventory; activity data, methods, emission factors and removals estimation • Prepare and develop LULUCF inventory of emissions and removals and deliver on time for incorporation into the national inventory • Participate in sectoral expert panels as required
DECC – Energy Analysis	• Energy modelling and projections	• Produce UK CO_2 projections

Table 1-4 Special Advisors to the UK GHG National Inventory Steering Committee[15]

Organisation	Role in relation to NISC	Key NISC responsibilities
Met Office/Bristol University	• Atmospheric measurements and interpretation at Mace Head, Ireland	• Provide atmospheric measurements and interpretation of these data collected at Mace Head, for use in inventory data verification • Prepare comparison between estimated and observed emissions for the NIR
External reviewers	• Representation of industries, industry organisations and independent experts in the development of the national inventory	• Other experts or representatives may be asked to participate in sectoral expert panels or to review key sources or sources where significant changes to methods, activity data or emission factors have occurred e.g. ONS, UKPIA, Oil & Gas UK, Tata Steel, Electricity Supply Industry etc.

[15] Attendance at NISC meetings is subject to specific requirements

1.2.2.5 UK Inventory Improvement Programme

Each year the inventory is updated to include the latest data available. Improvements to the methodology are made and are backdated to ensure a consistent time series. Methodological changes are made to take account of new research and data sources, any new guidance from IPCC, relevant work or emission factors from sources such as EMEP-CORINAIR and the US EPA, or from specific research programmes sponsored by DECC and other UK Departments.

The UK NIS has a formal inventory improvement programme, managed by the NISC. This achieves the dual aims of (i) progressing research to improve the UK GHGI data quality, and (ii) developing inter-Departmental/Agency working relationships to integrate inventory-related information from across Government.

The NISC helps prioritize improvements across the inventory. These improvements are designed to improve the transparency, accuracy, consistency, comparability, and completeness of the inventory. Small incremental improvements are made routinely to ensure the inventory uses the most accurate activity data and emission factors. A detailed and prioritised list of larger inventory improvement tasks is maintained by the inventory agency. The list is kept under review continually, and is formally reviewed annually at a NISC meeting. This list is prioritised by taking into account the Key Category Analysis (see **Section 1.5**), the quantitative uncertainty analysis, sector and pollutant expert judgements, and the future obligations of the inventory. The timing of the improvements and resourcing the work are important considerations for the NISC. The single national entity takes the final decision on timing and implementation of improvements to the inventory.

A table summarising the higher priority improvement items is being prepared and will be included in later versions of the NIR. The table will state the stakeholder leading the development work, and report the time frames and outputs of the improvements.

Integrated UK-DA GHGI improvement programme

During 2011-12, the UK GHG Inventory Improvement Programme implemented a number of specific research projects to address inventory uncertainties and reporting requirements, including:

- Analysis of EUETS data for UK and DA inventories, including assessment of the traded and non-traded components of the UK and DA inventories;
- The gas network leakage model used by the gas supply industry and used to underpin UK GHGI estimates was reviewed, and estimates for leakage at point of use have been revised to include estimates of emissions from gas use in cooking appliances in the domestic and commercial sectors;
- A review of energy data reporting from across the UK sought new data sources for solid and liquid fuel use, aiming to identify information that are sectorally and/or geographically resolved, in order to help inform improvements to the UK sector allocations and also the Devolved Administration inventory totals. This research included consultation and review of reports published by Her Majesty's Revenue and Customs, oil brokers, local councils, the Climate Change Agreements (a national policy reporting mechanism operated by DECC), the National Housing Model, and Welsh Government research into gas network expansion and fuel poverty;
- The inventory agency conducted a review of available literature to support future requirements in the UK to develop emission estimates from new GHG emission sources that may arise through future development of unconventional (shale) gas

resources in the UK. This review encompassed an assessment of new emission sources associated with shale gas exploration and production, the appropriate data reporting requirements in the UK inventory, including: source allocations, activity data needs, available emission factor data and associated uncertainties, anticipated responsibilities and reporting expectations of different UK organisations such as DECC and the IPPC regulatory agencies.

Agriculture inventory improvements

The UK GHG agricultural inventory is undergoing large improvements in order to quantify better the emissions and reduce uncertainty. Consortia of a wide range of scientific expertise has been put together to fulfil the requirements for improving the UK GHG agricultural inventory. In addition to this planned programme of improvement, a number of revisions were made to the inventory model for this reporting year; see **Section 6.1** for more information.

The agriculture improvement plan comprises:

1. Restructuring the inventory to improve spatial and temporal disaggregation and incorporation of Tier 2 methodology in those areas where both measurement and activity data are available. This work will also to allow the inventory to reflect the effect of mitigation strategies (DEFRA project AC0112).
2. Data mining to collate and review existing experimental agricultural data to deliver a set of country specific (Tier 2) emission factors and supporting farm practice data to enable an improved mapping of N_2O and CH_4 emissions for the United Kingdom with an assessment of uncertainty (DEFRA project AC0114).
3. Measurements at field scale of CH_4 emissions from enteric fermentation to develop Tier 2 methodology (DEFRA project AC0115).
4. Measurements at field scale of direct N_2O emissions at a range of UK sites to develop new country specific emission factors for inorganic N fertiliser, manure applications and urine and dung deposition by grazing livestock (EF1, EF3) (DEFRA project AC0116). In addition, measurements of indirect N_2O losses are planned at three sites where drainage is collected and the N_2O loss from leached/drained N is quantified (EF5).
5. Measurements at field scale of NH_3 emissions from manure management systems (DEFRA project AC0112).
6. Development of emission factors for N_2O from animal manure management systems from existing data (DEFRA project AC0112).
7. Assessment of the effect of mitigation strategies, specifically the use of nitrification inhibitors and optimising fertiliser timing on N_2O emission from soils

1.2.3 Overview of inventory preparation and management, including for supplementary information required under Article 7, Paragraph 1 of the Kyoto Protocol

For details of inventory preparation, see **Section 1.3**.

The Environment Agency is appointed as the UK Registry Administrator for the EU ETS/Kyoto Registry by DECC. The UK for this purpose comprises England, Wales, Scotland, Northern Ireland, Offshore installations and Gibraltar. The Environment Agency is a Government Agency.

Responsibilities of the Environment Agency include:

- Managing the contractors responsible for maintaining the computer systems (Siemens for software/hosting the Registry and Trustis for digital certificates);
- Conform to the Kyoto Protocol and the COP/MOP decisions as implemented by the UNFCCC;
- Conform to the EU Registries Regulations as amended from time to time;
- Allow access for authorised users. See Terms and Conditions at http://emissionsregistry.environment-agency.gov.uk/Default.aspx
- Act on instructions from Competent Authorities to manage accounts;
- Assist registry users.

DECC is currently implementing a Data Supply Agreement with the Environment Agency to ensure that the specific responsibilities of the Agency are more formally agreed.

1.3 INVENTORY PREPARATION

1.3.1 GHG Inventory

The present UK GHG inventory for the period 1990-2011 was compiled in accordance with the IPCC Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC, 1997a, b, c) and Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000), and the Good Practice Guidance for Land Use, Land-Use Change and Forestry (IPCC, 2003). As already highlighted in this Chapter, the KP-LULUCF is prepared by CEH, who also prepare Sector 5 LULUCF emission estimates.

1.3.2 Data collection, processing and storage

The data acquisition task provides the fundamental activity data from which the GHG inventory is constructed. The process starts in June with the annual requests for data. A database of contacts is used to track progress of the data acquired.

The following activities are carried out each year, in order, as the inventory is compiled:

Method improvement

- Improvements to calculation methods are implemented before the inventory is compiled. These improvements are in part based on recommendations of UNFCCC (In Depth Reviews, In Country Reviews), EC reviews, peer reviews, bilateral reviews and relevant research sponsored by DECC, Defra or other organisations.

Data request

- Requests for activity data and background data are issued to a wide range of data suppliers. Each request is issued with a unique code, and a database is used to track the request and the data supplied from that request.

Data verification

- Activity data received are examined. Anomalies are investigated, such as time series discrepancies, or large changes in values from the previous to the current inventory year.

Data processing

- Data are prepared to allow emissions of direct and indirect GHG to be estimated.

Emission estimation

- Provisional emissions are estimated using the most recent activity data available.

Emissions review

- A series of internal reviews are carried out to detect anomalies in the estimates (time series variations and year to year changes). Errors and omissions are then rectified.

Emissions reporting (including background data)

- Estimates of emissions are prepared for the various reporting formats (e.g. IPCC, UNECE etc including differing geographical coverages).

Report generation

- Draft reports are written to satisfy the reporting criteria of the various agencies, e.g. the IPCC.

Report review

- The reports are reviewed internally, by external contributing agencies, and by DECC. Errors and omissions are then rectified.

Report publication

- Final reports and data sets are then submitted via approved reporting routes, published in print and made available on publicly accessible web sites.

Data archiving

- At the end of each inventory cycle, all data, spreadsheets, databases and reports are archived, allowing all data to remain traceable, should it be needed in future years.

The system outlined above complies with the Tier 1 QA/QC procedures outlined in Table 8.1 of the Good Practice Guidance (IPCC, 2000).

Rothamsted Research and CEH, who are the sector experts for agriculture and LULUCF (including KP LULUCF), respectively, have their own systems in place for data collection. As the Inventory Agency responsible for compiling the overall inventory estimates, Ricardo-AEA receives completed emission estimates from these organisations as part of the annual data collection process, and combine the datasets within the CRF submissions and within the National Inventory Report.

Ricardo-AEA has a work programme in place with CEH to help harmonise the quality systems CEH use with those Ricardo-AEA use in the core GHG inventory.

1.3.3 Quality assurance/quality control (QA/QC) procedures and extensive review of GHG inventory

The QA/QC plan for the UK inventory is explained in **Section 1.6**. Additional details of QA/QC in the LULUCF sectors, see **Chapter 7**, **Section 7.9**.

1.4 METHODOLOGIES AND DATA SOURCES

1.4.1 GHG Inventory

The methods used to estimate emissions are described in detail in the relevant sections of this report. The direct and indirect GHGs reported are estimated using methodologies which mostly correspond to the detailed sectoral Tier 2/3 methods in the IPCC Guidelines.

Table 1-5 provides a brief summary of the methods used to estimate UK GHG emissions, which are described in more detail in the subsequent Chapters and Appendices.

Table 1-5 Summary of methods used to estimate emissions of the direct greenhouse gases

CRF sector	Comments on methods
1A	• Basic combustion module (see **Section 3.2.9.2.1**); and • Transport model (see **Section 3.2.11**).
1B	• Carbon Balance approach (See **Section 3.2.10.2**.); • DECC EEMS inventory (See **Section 3.3.2.2**); and • Gas leakage data from network operators (See **Section 3.3.2.2**).
2A	• Cement production: IPCC Tier 2 approach (see **Chapter 4**, **Section 4.2.2**).
2B	• Emissions calculated based on data from industry and the Pollution Inventory; and • Carbon emissions from certain non-energy uses (NEU) of fuel reported here.
2C	• Iron and Steel - 2 stage carbon balance (see **Section 3.2.10.2**); and • Spreadsheet model to estimate emissions of F-gases.
2D	• Emissions calculated based on USEPA Compilation of Air Emission Factors; and • Emissions calculated based on Industry and Government data sources.
2E, 2F	• Spreadsheet model to estimate emissions of F-gases
3A, 3B, 3C, 3D	• (No direct GHGs emitted from these sectors)
4A	• Emissions calculated based on animal population data and appropriate EFs
4B	• Emissions calculated based on animal population data and appropriate EFs
4D	• IPCC recommended methodology
4F	• Emissions calculated based on IPCC methodologies and USEPA EFs
5A, 5G	• C-Flow model to estimate emissions from forest planting and management
5B, 5C, 5E	• Land use change matrix and soil carbon model to estimate emissions from land use change • IPCC recommended methodology for other emissions and removals
5D	• Spreadsheet model to estimate emissions from peat extraction
6A	• The MELmod model
6B	• IPCC default method and the data from operator returns to the regulator
6C	• Uses country specific emission factors, partially based on Pollution Inventory data

The sources of data used are documented in the relevant sections of this NIR though much of the activity data are taken from the key publications listed in **Table 1-6**. All sources are updated annually.

Table 1-6 Summary of sources of activity data used to estimate greenhouse gas emissions

Source (and publisher)	**Relevant activity data contained in the source**
Digest of UK Energy Statistics (UK Department of Energy and Climate Change)	• Energy statistics for the UK (imports, exports, production, consumption, demand) of liquid, solid and gaseous fuels; and • Calorific values of fuels and conversion factors.
Emissions Trading System (EU ETS regulatory agencies in the UK; data supplied via UK Department of Energy and Climate Change)	• Emissions from installations and characteristics of fuels consumed. • Energy data are aggregated by sector and used to inform inventory estimates. • Fuel quality data are used to derive up to date carbon emission factors for major fuels in energy intensive sectors.
Transport Statistics GB (UK Department for Transport)	• Vehicle km according to vehicle type and road type: • Vehicle licensing statistics (split in vehicle km by fuel type); and • Selected domestic and international civil aviation aircraft km flown.
Northern Ireland Statistics: Inventory of Statutory Releases, transport data (NI Department of the Environment, NI Department for Regional Development)	• Traffic count and vehicle km data for Northern Ireland; and • Information on regulated processes in NI.
Civil Aviation Authority	• Detailed domestic and international civil aviation aircraft km flown.
Pollution Inventory (Environment Agency)	• Information on emissions from regulated processes in England and Wales.
Scottish Pollutant Release Inventory (Scottish Environment Protection Agency)	• Information on regulated processes in Scotland.
United Kingdom Petroleum Industry Association	• Refinery emissions; • Lead and sulphur contents of fuels, benzene content of petrol, RVP of petrol.
Environmental Emissions Monitoring System (EEMS) (DECC Offshore Inspectorate)	• Detailed inventory of oil and gas emissions.

Source (and publisher)	Relevant activity data contained in the source
UK Iron and Steel Industry Annual Statistics (International Steel Statistics Bureau)	• Energy production and consumption in the Iron and Steel industry; and • Other statistics regarding the Iron and Steel industry.
United Kingdom Minerals Yearbook (British Geological Society)	• Statistical data on minerals production, consumption and trade.
Annual Abstract of Statistics (Office for National Statistics)	• Population data.
Department for Transport	• Automatic Number Plate Recognition (ANPR) data used to help define fleet composition on different road types in the UK.

1.5 DESCRIPTION OF KEY SOURCE CATEGORIES

1.5.1 GHG Inventory

Key categories are defined as the sources of emissions that have a significant influence on the inventory as a whole, in terms of the absolute level of the emissions, the trend, or both. **Table 1-7**, **Table 1-8, Table 1-9** and **Table 1-10** summarise the key source categories, for 2011 (the latest reported year), and the base year, derived from the IPCC Approach 1 uncertainty analysis. Tables are included for the analysis with and without LULUCF. Details of the key source category analysis are given in **Annex 1**, including an analysis of key source categories in the base year. A trend cannot be calculated for the base year alone, and so the tables for the base year only contain key source categories identified by level.

Following IPCC good practice, a qualitative analysis of the inventory has been made to identify key categories. Details of this analysis are given in **Annex 1**. Emissions from cement production (2A1) have been identified as a key category.

Table 1-7 Key Source Categories for the latest reported year (including LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A(stationary)	Oil	CO_2	Level
1A	Natural Gas	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
2A1	Cement Production	CO_2	Qualitative
2B5	Non-energy use of products	CO_2	Level
5A	5A LULUCF	CO_2	Level
5B	5B LULUCF	CO_2	Level

IPCC source category	Fuel/Activity	GHG	Reason (s)
5C	5C LULUCF	CO_2	Level
5E	5E LULUCF	CO_2	Level
4A	Enteric Fermentation	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level, Trend
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level, Trend
1A3b	Auto Fuel	N_2O	Level
2B	Nitric Acid Production	N_2O	Trend
4B	Manure Management	N_2O	Level, Trend
4D	Agricultural Soils	N_2O	Level, Trend
6B	Wastewater Handling	N_2O	Level, Trend
2	Industrial Processes	HFC	Level

Table 1-8 Key Source Categories for the base year (including LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A	Coal	CO_2	Level
1A(stationary)	Oil	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
2A1	Cement Production	CO_2	Qualitative
5A	5A LULUCF	CO_2	Level
5B	5B LULUCF	CO_2	Level
5C	5C LULUCF	CO_2	Level
5E	5E LULUCF	CO_2	Level
1B1	Mining & Solid Fuel Transformation	CH_4	Level
1B2	Oil & Natural Gas	CH_4	Level
4A	Enteric Fermentation	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level
1A3b	Auto Fuel	N_2O	Level
2B	Adipic Acid Production	N_2O	Level
2B	Nitric Acid Production	N_2O	Level
4B	Manure Management	N_2O	Level
4D	Agricultural Soils	N_2O	Level
6B	Wastewater Handling	N_2O	Level
2	Industrial Processes	HFC	Level

Table 1-9 Key Source Categories for the latest reported year (excluding LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A(stationary)	Oil	CO_2	Level
1A	Natural Gas	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
2A1	Cement Production	CO_2	Qualitative
2B5	Non-energy use of products	CO_2	Level
4A	Enteric Fermentation	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level, Trend
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level, Trend
1A3b	Auto Fuel	N_2O	Level
2B	Nitric Acid Production	N_2O	Trend
4B	Manure Management	N_2O	Level, Trend
4D	Agricultural Soils	N_2O	Level, Trend
6B	Wastewater Handling	N_2O	Level, Trend
2	Industrial Processes	HFC	Level

Table 1-10 Key Source Categories for base year (excluding LULUCF)

IPCC source category	Fuel/Activity	GHG	Reason (s)
1A	Coal	CO_2	Level
1A(stationary)	Oil	CO_2	Level
1A3b	Auto Fuel	CO_2	Level
2A1	Cement Production	CO_2	Qualitative
1B1	Mining & Solid Fuel Transformation	CH_4	Level
1B2	Oil & Natural Gas	CH_4	Level
4A	Enteric Fermentation	CH_4	Level
6A	Solid Waste Disposal	CH_4	Level
1A1&1A2&1A4&1A5	Other Combustion	N_2O	Level
1A3b	Auto Fuel	N_2O	Level
2B	Adipic Acid Production	N_2O	Level
2B	Nitric Acid Production	N_2O	Level
4B	Manure Management	N_2O	Level
4D	Agricultural Soils	N_2O	Level
6B	Wastewater Handling	N_2O	Level
2	Industrial Processes	HFC	Level

1.5.2 KP-LULUCF analysis

A separate uncertainty analysis has been completed for the Key Categories for Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol. The full details of this analysis are given in Table NIR 3, reproduced in **Table A1.2.1** in **Annex 1**. This analysis indicates the key categories of emissions and removals are (KP category, gas, associated UNFCCC category):

- Afforestation and Reforestation, CO_2, Conversion to Forest Land
- Deforestation, CO_2, Conversion to Grassland; conversion to Settlements
- Forest Management, CO_2, Conversion to Forest Land

1.6 QA/QC PLAN

This section presents the QA/QC system for the UK GHGI, including verification and treatment of confidentiality issues. The current system complies with the IPCC Tier 1 procedures outlined in the Good Practice Guidance (IPCC, 2000) and has been extended to include a range of on-going bespoke sector specific QA/QC activities to comply with Tier 2 requirements. Ricardo-AEA, the Inventory Agency, is also fully accredited to BS EN ISO 9001:2008 (see **Box 1** below). This accreditation provides additional institutional standards which the inventory agency has to apply to all projects and ensures that the wider company conforms to good practice in project management and quality assurance.

Source specific QA/QC details are discussed in the relevant sections of this NIR. Where there is currently insufficient detail available to provide source specific QA/QC, more general information is given in the relevant section of the NIR.

1.6.1 Description of the QA/QC current system

The UK Greenhouse Gas Inventory and the National Atmospheric Emissions Inventory are compiled and maintained together by Ricardo-AEA (the Inventory Agency), on behalf of the Department for Energy and Climate Change (DECC) and the Department for Food and Rural Affairs (DEFRA). Ricardo-AEA prepares the GHG submissions to the EC under the EUMM and to the UNFCCC.

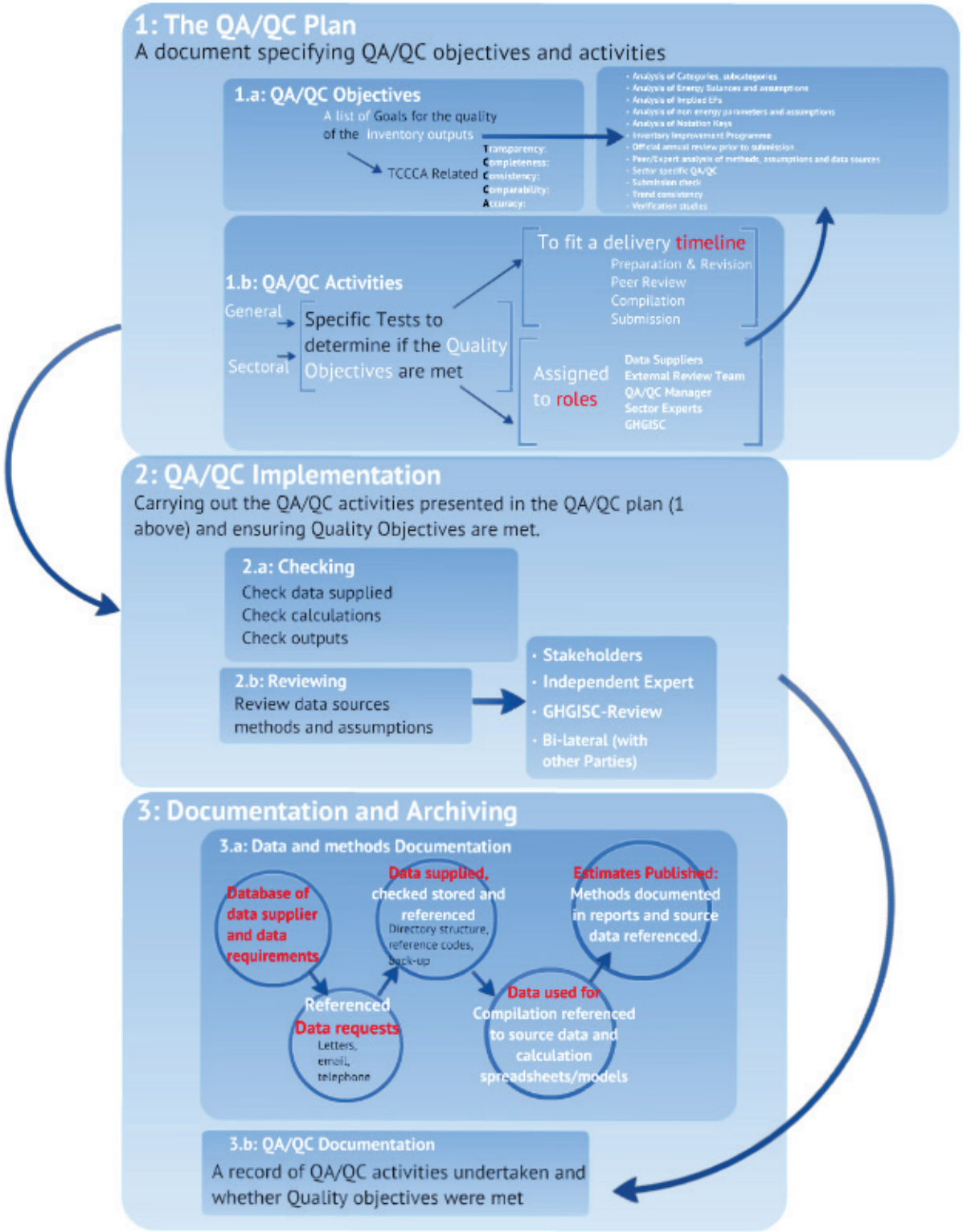
The data compilation for some source sectors of the UK inventory are performed by other contractors (i.e. Rothamsted Research compile the agriculture sector, CEH compile the land use, land-use change and forestry sector). Much of the data received by Ricardo-AEA for the UK GHGI compilation come from other government departments, agencies, research establishments or consultants working on behalf of UK government or for trade associations. Some of the organisations (e.g. DECC, the Office of National Statistics and British Geological Survey) qualify as the UKs National Statistical Agencies referred to in the Guidance and abide by strict statistical QA/QC standards. Other organisations (e.g. CEH, providing the LULUCF estimates and the Environment Agency, providing regulated point source data) supply important datasets for the Inventory and have their own QA/QC systems.

Whilst these organisations have their own QA/QC systems, Ricardo-AEA is responsible for co-ordinating inventory-wide QA/QC activities relating to the submitted datasets. In addition, Ricardo-AEA is working continuously with organisations supplying data to the GHG inventory to encourage them to demonstrate their own levels of QA/QC that comply with either IPCC Good Practice Guidance or the UK's National Statistics standards.

An overview of the UKs GHGI QA/QC system is illustrated in **Figure 1-4** below. The QA/QC system includes three core components.

1. **The QA/QC plan** which is maintained by the GHGI's QA/QC manager (at Ricardo-AEA) and defines the specific Quality Objectives and QA/QC activities required in undertaking the compilation and reporting of GHG estimates. The plan also assigns roles, responsibilities and a timeline for completion of QA/QC activities.
2. **QA/QC implementation** includes the physical undertaking of the QA/QC activities throughout the data gathering, compilation and reporting phases of the annual emission estimation cycle and in accordance with the QA/QC plan.
3. **Documentation and archiving** which includes a) transparent documentation of all data sources, methods, and assumptions used in estimating and reporting the GHG inventory; and b) transparent documentation of all QA/QC implementation including records of activities undertaken, findings/issue logs, recommendations and any necessary actions taken or planned.

Figure 1-4 QA/QC system used within UK greenhouse gas inventory



Box 1: BS EN ISO 9001:2008 Accreditation

In addition to the UK's own GHGI specific QA/QC system, through Ricardo-AEA Ltd, the Inventory has been subject to ISO 9000 since 1994 and is now subject to BS EN ISO 9001:2008. It is audited by Lloyds and the Ricardo-AEA internal QA auditors. The NAEI has been audited favourably by Lloyds on three occasions in the last 12 years. The emphasis of these audits was on authorisation of personnel to work on inventories, document control, data tracking and spreadsheet checking, and project management. As part of the Inventory management structure there is a nominated officer responsible for the QA/QC system – the QA/QC Co-ordinator. Ricardo-AEA Ltd is currently accredited to BS EN ISO 9001:2008. Lloyds Register Quality Assurance carried out a three yearly recertification audit of AEA in September and October 2011. Ricardo-AEA Ltd successfully passed the recertification, with no major non compliances, and a new certificate was issued. Ricardo-AEA is currently certificated both for the Quality Assurance ISO 9001:2008, including TiCKIT, and Environmental Management System ISO 14001 standard.

Specific details of the QA/QC plan, implementation, documentation and archiving are provided below.

1.6.1.1 Scope of the QA/QC plan

The QA/QC plan oversees:

1. Calculation of greenhouse gas estimates and reporting to UNFCCC and EUMM (including emissions and removals from all sources and gases);
2. Calculation of air pollutant estimates and reporting to UNECE (including emissions from all sources and pollutants);
3. Calculation of estimates and reporting to UK National Statistics.

1.6.1.2 Quality Objectives

The key objectives of the QA/QC plan are to ensure that the estimates in the GHG inventory are of a suitably high quality, and in achieving this, the principles of Transparency, Completeness, Consistency, Comparability and Accuracy (TCCCA) are met. The plan ensures the estimates of emissions are:

Transparent

- in the description of methods, assumptions, data sources used to compile estimates in internal (spreadsheets and other calculation tools) and published material (e.g. the NIR) and on the inclusion of national and EU wide assumptions (e.g. source category detail and the split between EUETS and non EUETS sources, implementation of policies and measures, carbon contents of fuels, site specific estimates, national statistics such as population, GDP, energy prices, carbon prices etc.);
- in the documentation of QA/QC activities and their implementation using internal checklists and summarised in relevant public material (e.g. NIR).

Complete

- and include all relevant (anthropogenic) emission/removal activities, using representative **data** for the national territory for socio-economic assumptions and policies and measures for all required years, categories and, gases and scenarios.

Consistent

- across trends in emissions/removals for all years (especially where applicable between the historic and projected estimates) and that there is internal consistency in aggregation of emissions/removals.

Comparable

- with other reported emission/removal estimates through use of the latest reporting templates and nomenclature consistent with reporting requirements. Using the , the correct IPCC category level and consistent units for expressing mass of emissions/removals by gas., split between EUETS and non EUETS sources, scenarios, units for parameters and of input parameters with EU assumptions on (e.g. energy prices, energy demand, carbon price, population etc.).

Accurate

- ensuring the most accurate methods are used in the application of methods, minimising the uncertainty in assumptions and in use of data sources for the estimates and inclusion of national assumptions.

1.6.1.3 Roles and Responsibilities

Specific responsibilities have been assigned to the different QA (review) and QC (checking) activities and to different roles within the compilation and reporting process. A QA/QC manager co-ordinates all QA/QC activities and manages the contributions from data suppliers, sector experts and independent experts. The following responsibilities are outlined in the QA/QC plan:

- **QA/QC Manager**: Maintains the QA/QC plan, sets quality objectives, co-ordinates QA/QC activities and undertakes cross cutting QA/QC activities;
- **Sectoral Experts**: Perform sector specific review and checking activities and report to the QA/QC Manager. Sector Experts also liaise with **Data suppliers** and other key stakeholders to review estimates and check supplied material;
- **Knowledge Leaders**: Manage periodic review and perform final checking activities on data and report submissions. Knowledge Leaders have been selected for this role due to their recognised technical experience and authority in the subject area;
- **External Review experts: Provide** expert**/peer review of projections for specific sectors and report to the QA/QC Manager**.

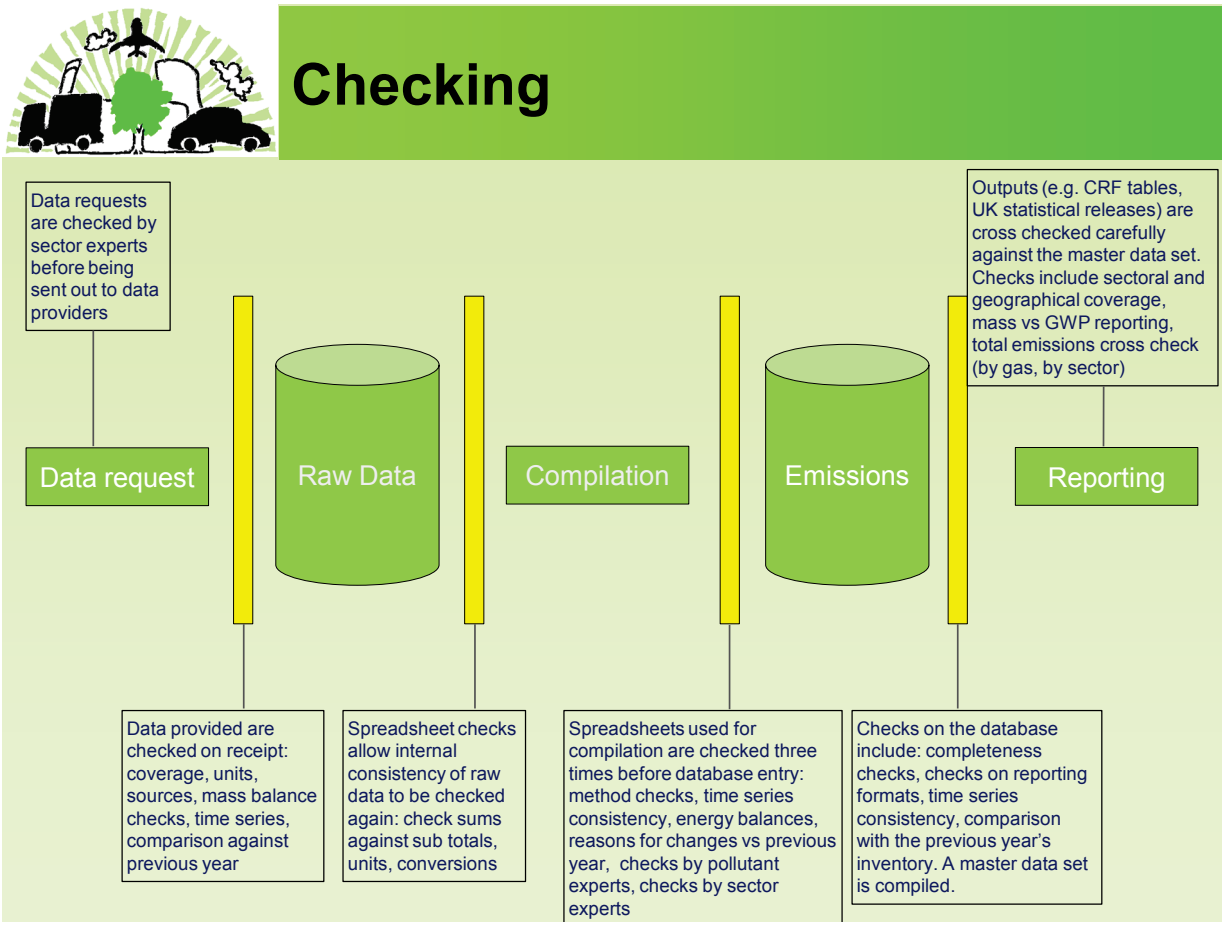
1.6.1.4 Timeline

The QA/QC plan sets out a detailed timeline for QA/QC checks. The timeline is designed to fit in with compilation and reporting requirements for all UK GHG and Air Pollutant reporting commitments.

1.6.1.5 Quality Control and Documentation

The UK's GHGI Quality Control (checking, documentation and archiving) occurs throughout the data gathering, compilation and reporting cycle. **Figure 1-3** illustrates the process of data checks used within the UK greenhouse gas inventory. The yellow vertical bars symbolise 'gates' through which data does not pass until it meets the quality criteria and the appropriate checks have been performed.

Figure 1-3 Summary of the system of data checks used within the UK greenhouse gas inventory



Checking and documentation is facilitated by specific custom data storage and handling systems and procedures developed for the GHGI compilation that include:

1. **A database of contacts (the "contacts database")** containing uniquely referenced data suppliers data, users, detailed data requirement specifications (including requirements for supplier QA/QC and uncertainty information) and data supplied to and delivered from the GHGI. This database tracks all data sources and suppliers used for the estimation of emissions/removals with unique references that are used to tag datasets through the inventory compilation process. The contacts database also tracks all products supplied from the GHGI including formal submissions and data supplied in response to informal and ad-hoc data requests.

2. **Individual data processing tools** are used to prepare the majority of source data into suitable AD and EFs for UK emissions estimates. These data processing tools (spreadsheets and database models) include *QC procedures, summaries and source data referencing within them*. The QC procedures include embedded (in the tools) *sector specific checks* (e.g. energy/mass balance and default emission factor checks for country specific emission factors, and implied emission factor checking). The QC procedures, within each tool/spreadsheet, include *calculation input/output checking* cells and flags to identify calculation errors. *The QC summary* sheets in each tool/spreadsheet includes links to QC activities that need to be performed, flags for

the QC activities, their status and sign off; details of source data; key assumptions, methods, data processing activities and progress; the scope of activities, gases and years included; relationships with other processing spreadsheets (where inter-dependencies exist); records of authorship; version control and checking. All relevant *cells in the data processing spreadsheets are colour coded* for ease of reference indicating whether the cells are calculation cells, output cells, checking cells or data input cells. All input cells carry a reference to the unique data source and data supplier held in the contacts database so all source data can be traced back to its originator and date of supply. *All spreadsheets are subject to second-person checking* prior to data uploading to the NAEI database.

3. **A core database (NAEI database) of AD and EFs** with embedded tier 1 QC routines and data source and data processing referencing. The database provides the quality assured data source of emission/removal estimates used for reporting (including CRF population), responding to ad-hoc queries or deriving other downstream estimates (e.g. emissions by Devolved Administration and emissions by Local Authority). The detailed activity data and emission factor components for each estimate are held within the central database and include all sources, activities, gases/pollutants (GHGI and AQPI) and years. The majority of data in the database are imported directly from the individual data processing tools/spreadsheets (described above). *Data transparency:* All data points in the database carry a reference that pinpoints either the upstream data processing tools used to derive the data, the external data source and supplier or both. It also includes details of the date entered, the person uploading the data, its units (to ensure correct calculation), and a revision or recalculation code (which ensures that recalculations of historic data can be easily traced and summarised in reports). *Automated data import routines* used to populate the database minimise transcription errors and errors resulting from importing data that has not been properly checked. This process extracts output data from the upstream data processing tools/spreadsheets and can be controlled by the Inventory Agency via a data import dashboard. The automated system ensures that data is only uploaded to the database once it meets specified QA/QC criteria of data checking, completion and consistency. A number of *detailed QC checking queries*[16] are embedded within the database that support the annual QA activities defined in the QA/QC plan and include:
    a. Checks with previous submissions for changes due to recalculations or errors at a detailed level, (A designated auditor identifies sources where there have been significant changes or new sources. Inventory compilers are then required to explain these changes to satisfy the auditor)[17];
    b. Assessment of trends and time series consistency for selected key sources;
    c. Mass balance checks to ensure that the total fuel consumptions in the GHG inventory are in accordance with those published in the official UK Energy Statistics from DECC;
    d. Other activity data checks (e.g. production and consumption with official national statistics);
    e. Implied Emission Factor checks (assessing trends in IEF and comparison with previous submissions);
    f. A consistency check between IPCC output and CORINAIR formatted output.

[16] A full list is included in the QA/QC plan.

[17] This is somewhat more detailed than the recalculation explanations required by Table 8 in the CRF, as it is based on the more disaggregated source sectors used in the NAEI database.

4. **Data extraction checking routines and procedures** allow data exported from the NAEI database and entered into reporting tools (e.g. the CRF Reporter tool) to be finally checked against the direct database output totals to ensure that any inconsistencies are identified and rectified prior to submission. This includes interrogating the output xml from the CRF software and comparing this against a series of queries from the NAEI database to compare both emissions and activity data.

5. **Official annual reports to UNFCCC** provide full documentation of inventory estimation methodologies, data sources and assumptions by source sector, key data sources and significant revisions to methods and historic data, where appropriate. The annual report to the UNFCCC includes details of planned prioritising improvements identified by the Inventory Agency and agreed by the National Inventory Steering Committee, and from Expert and Peer Reviews. Any data presented in reports are checked against accompanying submission datasets and the NAEI database.

6. **Archiving** so that at the end of each reporting cycle, all the database files, spreadsheets, on line manuals, electronic source data, records of communications, paper source data, output files representing all calculations for the full time series are frozen and archived on a central server. An annual report outlining the methodology of the inventory and data sources is produced. Electronic information is stored on hard disks that are regularly backed up. Paper information is archived in a Roller Racking system with a simple electronic database of all items references in the archive.

1.6.1.6 Quality Assurance and Verification

This section describes a number of specific QA activities and procedures.

1.6.1.6.1 NISC annual Review

Annually and prior to submission the National Inventory Steering Committee (NISC) review the emissions inventory datasets, including recalculations. The NISC is tasked with the official consideration and approval of the national inventory prior to submission to the UNFCCC. The NISC comprises key stakeholders (see Institutional arrangements section) who have an understanding of the GHG estimates and input data sources.

1.6.1.6.2 Stakeholder Consultation with Key Data Providers

The GHGI team have an on-going programme of one-to-one meetings and engage in detailed discussions with Key Data Providers to help ensure that the inventory is using the best available data. The UK plans and participates in a series of one-to-one meetings and engagement activities each year.

Stakeholder consultation activities completed to date include:

Department of Energy and Climate Change

- A series of meetings, emails and phone calls with the DECC energy statistics team that produces the Digest of UK Energy Statistics (DUKES) and the regulators of the EUETS data collection and reporting systems to determine sector-specific and fuel-specific quality parameters for the UK; check and resolve any outlier data or inconsistencies between CITL data and source data from regulators; compare sector-

and fuel-specific activity data published in UK energy statistics against the EUETS data for the latest year;

- Linked to the EUETS analysis in the bullet point above, data inconsistencies between DUKES and the EUETS for OPG use in the chemical / petrochemical / other industry sectors were identified. The inventory agency consulted with the DECC DUKES team, EUETS regulators, site-specific regulatory contacts (Site Inspectors, Process Engineers), and directly with plant operators to assess the source and scale of the emissions. Through this research, new activity data for industrial use of OPG was estimated across the time series (reported under 1A2f). As in previous years, data discrepancies between DUKES and EUETS for the refinery sector were noted and resolved through consultation with the DECC DUKES team, EUETS regulators and checked against data provided by the refinery sector trade association, UKPIA;
- Additional consultation with the DECC DUKES team has clarified data management within the UK energy statistics compilation system for coke oven coke, shipping fuel use and bunker definitions, to ensure correct use of DUKES data within the GHGI;
- Consultation with the DECC Offshore Inspectorate, oil and gas sector contractors and individual site operators to resolve data gaps and inconsistencies within reported emissions data for onshore oil and gas terminals and offshore installations, including to review and resolve data discrepancies from the EUETS and EEMS emission reporting systems. In the 1990-2011 inventory reporting cycle, the inventory agency has been able to access full details of EUETS information for the offshore oil and gas installations for the first time, due to improvements in data management systems by the UK regulators (DECC). This has enabled the inventory agency to improve the accuracy of source allocation of emissions for the sector;
- Linked to the item above, the inventory agency has also consulted with the DECC Offshore Inspectorate and the Health and Safety Executive to research available data on upstream oil and gas well blow-outs. This has led to the identification of some potentially useful annual estimates of such incidents on the UK Continental Shelf, although this has not proved sufficient to enable new emission estimates for these sources to be estimated. The inventory agency has also emailed IPCC chapter authors from Norway and Canada, as well as inventory agency counterparts in other countries, to seek any data or methodological advice on deriving estimates of methane emissions from oil and gas well blowouts. This is an area for further research in the UK inventory;

Department for Transport

- Consultation with the Department for Transport Traffic Statistics team to discuss continuous provision of ANPR data and potential new data on vehicle speeds;
- Consultation with the Department for Transport on their new Rail Emissions Model for updating the rail emissions inventory as part of the improvement programme;

Department for Environment, Food and Rural Affairs

- Consultation with Defra, the water industry regulator (OFWAT), the Environment Agency for England and Wales and water and sewerage companies in the UK, to review the sector emission estimates of methane emissions from waste water treatment and sewage sludge treatment and disposal. The inventory agency met with Carbon Managers from most of the UK water companies via the UK Water Industry Research forum and has procured activity and emissions data from more water

companies to improve the completeness of estimates in the latest inventory, although we still do not have 100% reporting from UK water companies for municipal waste water systems. New information and reports obtained from Defra and the Environment Agency have enabled new estimates of emissions from industrial waste water treatment to be compiled across the time series;

- Consultation with the Environment Agency of England and Wales (EA) and Defra has led to a revision of the time series of carbon content of MSW incinerated within energy from waste facilities in the UK, leading to a more representative UK carbon emission factor. Furthermore, research with the EA and Defra has progressed our understanding of the data availability for landfill methane flaring and use in gas engines. More research is needed to develop these new data and determine whether any revisions to UK assumptions / factors on methane utilisation should be considered in future inventory estimates. Currently the dataset is too limited to be regarded as representative of UK landfill activity.

Environmental Regulators

- Meetings, teleconferences and emails with sector experts and emission inventory analysts from the environmental regulatory agencies in the UK (EA, SEPA, NIEA) and plant operators to explore site-specific and sector-wide issues to address source-specific emission factor uncertainties and obtain up to date information regarding site-specific activities, abatement and changes to plant design or scope of reporting. This has helped to address data reporting issues for one of the integrated steelworks in the UK, a number of chemical companies and a large coal-fired autogenerator;

Other data providers

- Consultation with natural gas distribution network operating companies to: (i) obtain new data on the estimated gas leakage from the transmission system to improve inventory transparency, (ii) a review of the time series of gas leakage through the distribution network to address a step-change in the previous inventory time series to improve the accuracy and consistency of the inventory time series, and (iii) to obtain new data on actual (rather than weather-corrected) annual gas demand through all of the regional distribution networks, in order to improve the accuracy of the aggregated UK estimates for natural gas composition;
- Consultation with the Mineral Products Association, British Glass and the British Geological Survey to review data inconsistencies on national activity data for limestone and dolomite use, access sector-specific production statistics and therefore to derive improved activity data for several industry sectors;
- Consultation with the team that compiles the RESTATS database, which informs the DUKES renewable energy statistics for the UK, to compare the scope and data sources that underpin the national statistics on biomass and biofuels against data provided directly by industry-specific publications and datasets;
- Consultation with colliery operators and UK Coal, combined with review of annual reports on coal mine methane use in the UK have led to a small revision in the estimates of methane recovery and emissions in recent years. Previously the inventory estimates were based on data from mines that accounted for around 80% of UK production, and this consultation has enabled a more complete, representative UK dataset to be used in the inventory.

1.6.1.6.3 Integrated UK and Devolved Administration GHG Inventory Improvement Programme

During 2011-12, the integrated UK-DA GHGI improvement programme implemented a number of specific research projects to address inventory uncertainties and reporting requirements, including:

- Analysis of EUETS data for UK and DA inventories, including assessment of the traded and non-traded components of the UK and DA inventories;
- The gas network leakage model used by the gas supply industry and used to underpin UK GHGI estimates was reviewed, and estimates for leakage at point of use have been revised to include estimates of emissions from gas use in cooking appliances in the domestic and commercial sectors;
- A review of energy data reporting from across the UK sought new data sources for solid and liquid fuel use, aiming to identify information that are sectorally and/or geographically resolved, in order to help inform improvements to the UK sector allocations and also the Devolved Administration inventory totals. This research included consultation and review of reports published by Her Majesty's Revenue and Customs, oil brokers, local councils, the Climate Change Agreements (a national policy reporting mechanism operated by DECC), the National Housing Model, Welsh Government research into gas network expansion and fuel poverty;
- The inventory agency conducted a review of available literature to support any future requirements in the UK to develop emission estimates from new GHG emission sources that may arise through future development of unconventional (shale) gas resources in the UK. This review encompassed an assessment of new emission sources associated with shale gas exploration and production, the appropriate data reporting requirements in the UK inventory, including: source allocations, activity data needs, available emission factor data and associated uncertainties, anticipated responsibilities and reporting expectations of different UK organisations such as DECC and the IPPC regulatory agencies.

1.6.1.6.4 Reviews

The UK's programme of bilateral and external peer reviews is managed by the NISC as part of the improvement programme. Bilateral reviews are initiated with other countries as a means to learn from good practice on other countries as well as to provide independent expertise to review estimates. The UK has participated in a number of bilateral exchanges and the current contract makes allowances for biennial bilateral reviews.

Starting in 2002, the UK implemented a programme of peer reviews by experts outside of the organisation responsible for the estimates. The UKs programme of peer review is managed by the NISC as part of the improvement programme. External Peer review is applied in two cases:

1. When new methods have been developed for important source categories;
2. On a rolling programme to determine whether methods should be improved due to the availability of new datasets and assumptions (focussing on key categories).

Review activities to date are summarised in the table below.

Table 1-11 Summary of Peer and Bilateral review activities

Review description	Summary
2012: Peer review of all except Sector 5. Conducted by EC Technical Expert Review Team	The review focussed on non LULUCF sectors and provided a report for each Member State (including the UK) highlighting recommendations for improvements as well as documentation of any revised estimates as a result of the review. The UK made 3 minor (in total ~ 0.1%) revisions as recommended by this review for lime production and burning of biomass for energy to address underestimates, and for Dairy Cattle to address an over estimate. The review also presented another 20 recommendations for the UK to consider.
2011: Bilateral review of F-gases (2E, 2F) between Austrian, German and UK inventory teams	The object of the review was to share methods, experiences and potential data sources across the three teams and to provide recommendations on how to improve each of the inventories for these sectors. The recommendations for the UK have been added to the UK GHGI improvement programme for consideration by the NISC, and some are now being implemented.
2010 and **2008**: Peer review of Refrigeration and air conditioning (2F1) with Industry experts; SKM Enviros	Assumptions about leakage rates and the mix of HFC fluids in each sub-sector were peer reviewed, by a workshop of experts in 2008. Losses during manufacture/initial charging and at decommissioning in the original refrigeration sector model were generally based on factors recommended by the IPCC or the recommendations from this workshop. The model was again peer reviewed by SKM Enviros in 2010, and has since been replaced by new research in 2011.
2009: Peer review of LULUCF (5). DECC funded peer review, CRH independent team	DECC funded an external peer review of the research programme that provides LULUCF emissions estimates to the Greenhouse Gas Inventory in 2009. In addition, in 2009 the LULUCF inventory project was audited by an independent CEH team to confirm compliance with the Joint Code of Practice, where the project was praised for its high standards.
2008: Bilateral review of Agriculture (4) with the French inventory team	The objectives of the review were to develop emissions inventory capacity in collaboration with France, and to provide elements of expert peer review to meet quality assurance requirements under national inventory systems e.g. Article 5, paragraph 1, of the Kyoto Protocol and European Union Monitoring Mechanism (EUMM) e.g. 280/2004/EC. Specific activities undertaken included sharing good practice between the UK and France and the development of ideas for efficient future technical collaboration.
2005: Peer review of Adipic acid production (2B3) with Defra, Ricardo-AEA, plant operators, the Met Office	The review included: plant design, abatement design, abatement efficiency and availability, emission measurement techniques, historic stack emission datasets and data to support periodic fluctuations in reported emissions. These discussions clarified the relationship between annual emission totals reported by the plant operators and emissions verification work conducted by the Met Office using ambient N_2O concentration measurements from the Mace Head observatory in Ireland. The meeting prompted exchange of detailed plant emissions data and recalculation of back-trajectory emission models.
2002: Peer review of Fuel Combustion (1A) by Tim Simmons (UK energy statistician)	This review provided recommendations which have now been implemented, including: an improved method for estimating emissions from domestic and international civil aviation; a review of the carbon emission factors used in the UK GHG inventory; and a review of the proportion of recycled lubricants burnt.

1.6.1.7 Capacity building and knowledge sharing

The UK actively participates in capacity building and knowledge sharing activities with other countries. These initiatives are usually led by the NISC but also include some projects lead by Ricardo-AEA and funded by the EU and EEA through the European Topic Centre on Air and Climate Mitigation. The list below highlights some recent examples of these activities.

1. Knowledge sharing with the Russian statistical agency who compile the GHG inventory for Russia.
2. Capacity building activities in South Africa in the agricultural sector.
3. Knowledge sharing with the Sao Paulo inventory team.
4. Capacity building activities in Saudi Arabia – assistance with the production of their second National Communication and suggestions for the improvements of their greenhouse gas inventory.
5. Work with the Malta Environmental Protection Agency to set up a National Inventory System to produce both greenhouse gas and air quality pollutant inventories.
6. The F-gases trilateral review with Austria and Germany included knowledge sharing between the three reporting parties.
7. Knowledge sharing with the Romanian GHG inventory team during December 2011 to support the improvement of energy sector reporting.
8. Knowledge sharing with the Chinese Energy Research Institute regarding the UK experience of integrating facility-level data into the national inventory and outlining all of the QA procedures that govern energy and emissions data from facility to sector to national level within the UK, to support their efforts in developing a national system of data management to account for GHG emissions, working from provincial and facility-level data.

1.6.2 Verification

DECC has a research programme that derives independent emission estimates for the UK using in-situ high-precision high-frequency atmospheric observations of the Kyoto gases and a range of other trace gases at the Mace Head Atmospheric Research Station on the west coast of the Republic of Ireland. The UK Met Office employs the Lagrangian dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) driven by 3D synoptic meteorology from the Unified Model to sort the observations made at Mace Head into those that represent northern hemisphere baseline air masses and those that represent regionally-polluted air masses arriving from Europe. The Met Office inversion modelling system, InTEM (Inversion Technique for Emission Modelling), is then used to estimate the magnitude and spatial distribution of the UK and European emissions that best support the observations and provide a fully independent estimate of annual emission trends for the UK. The technique has been applied to 2 year rolling subsets of the data.

A 3-year contract, awarded in early 2011 following a competition exercise, expands on this work by developing three new sites across the UK, at Angus (north of Dundee), Talcolneston (Norfolk), and Ridge Hill (Herefordshire), to create the UK-DECC (Deriving Emissions of Climate Change) network. The data from these additional sites will result in significant increases in spatial and temporal resolution, enabling Devolved Administration emission estimates to be calculated from Atmospheric Observations. The uncertainties associated with the UK emission estimates will also decrease.

The complete results of this verification and a more detailed description of the modelling method used are given in **Annex 10**.

1.6.3 Treatment of Confidentiality

Much of the data necessary to compile the UK inventory are publicly available. The main exception relates to the reporting of emissions from PFCs and HFCs from some sources. For example, private companies that have provided data to estimate emissions of these gases from training shoes have provided data on condition that the data remains confidential, and it is therefore not possible to report emissions of PFC or HFC species from this source in isolation. Therefore, a number of sources are reported in combination, and estimates of the total emissions in the main IPCC categories are provided.

In addition, industrial production data are commercially sensitive in a handful of cases, such as cement production and adipic acid production. For these sectors, whilst emissions data are reported openly, the production data (required within the CRF to derive Implied Emission Factors to enable cross-party benchmarking) are reported as confidential using the notation key "C".

Detailed EU ETS data are also supplied by the regulators to the Inventory Agency, which allows further analysis of the data to develop new emission factors or to cross check fuel use data with other sources. This detailed data set is not publically available, and therefore information obtained from the analysis of this data is suitably aggregated before it can be explicitly reported within the CRF tables or the NIR.

The UK National Inventory Reports from the 1999 NIR onwards, and estimates of emissions of GHGs, are all publicly available on the web; see http://naei.defra.gov.uk/ .

1.7 GENERAL UNCERTAINTY EVALUATION

1.7.1 GHG Inventory

The UK GHG inventory estimates uncertainties using both Approach 1 (error propagation) and Approach 2 (Monte Carlo simulation) described by the IPCC. Approach 1 provides estimates of uncertainty by GHG according to IPCC sector. Approach 2 considers the correlations between sources and provides estimates of uncertainty according to GHG in 1990 and the latest reporting year, and has now been extended to provide emissions by IPCC sector.

Approach 2 (Monte Carlo simulation) suggests that the uncertainty in the combined GWP weighted emissions of all the greenhouse gases is 15% in 1990 and 17% in 2011. The trend in the total GWP weighted emissions expressed as the fall between 1990 and 2011 is -29%, with 95% of the values found to lie within the range -26% to -31%. The source making the major contribution to the overall uncertainty is 4D – Agricultural soils.

A full description of the uncertainty analysis is presented in **Annex 7**. The uncertainty estimates for all gases are summarised in **Table A7.3.1**.

Uncertainty assessment and quantification of the LULUCF component inventory has been undertaken during 2007-2009 with particular focus on the forest carbon modelling components (van Oijen 2007; 2008; 2009). The carbon flow model, CFlow (Dewar and

Cannell 1992), is used to model carbon pools and fluxes in UK forests (described in Annex 3.7). The uncertainty arising from the inputs, parameters and model structure of CFlow has been examined, and it has also been compared with a more complex process-based model, BASFOR (van Oijen and Thomson, submitted). Full detail of the uncertainty work carried out can be found in **Chapter 11, Section 11.3.1.5**.

1.8 GENERAL ASSESSMENT OF COMPLETENESS

1.8.1 GHG Inventory

The UK GHG inventory aims to include all anthropogenic sources of GHGs. **Annex 5** shows sources of GHGs that are not estimated in the UK GHG inventory, and the reasons for those sources being omitted.

Completeness of the KP-LULUCF inventory is reported in **Chapter 11, Section 11.3.1.2**.

2 Trends in Greenhouse Gas Emissions

2.1 DESCRIPTION AND INTERPRETATION OF EMISSION TRENDS FOR AGGREGATED GREENHOUSE GAS EMISSIONS

Total emissions of direct greenhouse gases have decreased by 29% between 1990 and 2011. This decline is driven predominantly by a decrease in emissions from the energy sector – particularly 1A1. The following sections of this report provide an interpretation of this trend, focusing on the trends by gas, and by source sector.

Unless otherwise indicated, percentages quoted are relative to net emissions (i.e. emissions including removals from LULUCF). The geographical coverage used for calculating all figures is full UNFCCC coverage – i.e. UK including Crown Dependencies and relevant Overseas Territories.

The percentage changes presented in this chapter are calculated from emission estimates held at full precision within a database, therefore they may differ slightly from those that could be calculated from rounded figures presented in this report.

Table 2-1 UK Greenhouse Gas Emissions by Gas, 1990-2011 in Mt CO2e

Emission Year	CO_2	CH_4	N_2O	HFCs	PFCs	SF6	**Total**
1990	593.54	99.16	68.30	11.39	1.40	1.03	**774.81**
1991	600.68	98.34	68.48	11.86	1.17	1.08	**781.61**
1992	583.47	96.55	63.65	12.35	0.57	1.12	**757.72**
1993	568.76	93.32	59.00	13.02	0.49	1.17	**735.76**
1994	562.52	85.96	59.47	13.94	0.49	1.18	**723.56**
1995	555.31	85.25	58.02	15.33	0.46	1.24	**715.60**
1996	576.45	83.03	57.82	16.57	0.48	1.27	**735.61**
1997	551.85	78.49	58.14	19.00	0.40	1.23	**709.10**
1998	556.00	74.25	57.93	16.90	0.39	1.26	**706.73**
1999	546.57	69.25	47.38	10.26	0.37	1.43	**675.25**
2000	554.81	65.02	46.49	9.34	0.46	1.80	**677.91**
2001	566.02	59.33	43.79	10.27	0.38	1.43	**681.22**
2002	549.25	56.25	42.03	10.73	0.32	1.51	**660.10**
2003	559.38	52.26	41.56	11.93	0.28	1.32	**666.74**
2004	560.10	50.68	42.14	11.21	0.34	1.13	**665.59**
2005	556.09	48.50	41.23	12.11	0.30	1.11	**659.34**
2006	554.80	47.49	39.10	12.79	0.30	0.87	**655.35**
2007	545.82	46.36	38.41	13.10	0.22	0.79	**644.70**
2008	533.19	45.02	37.38	13.69	0.20	0.71	**630.19**
2009	482.66	43.72	35.35	14.03	0.15	0.66	**576.57**
2010	499.88	43.02	35.92	14.39	0.22	0.69	**594.11**
2011	460.69	42.06	34.81	14.65	0.33	0.61	**553.15**

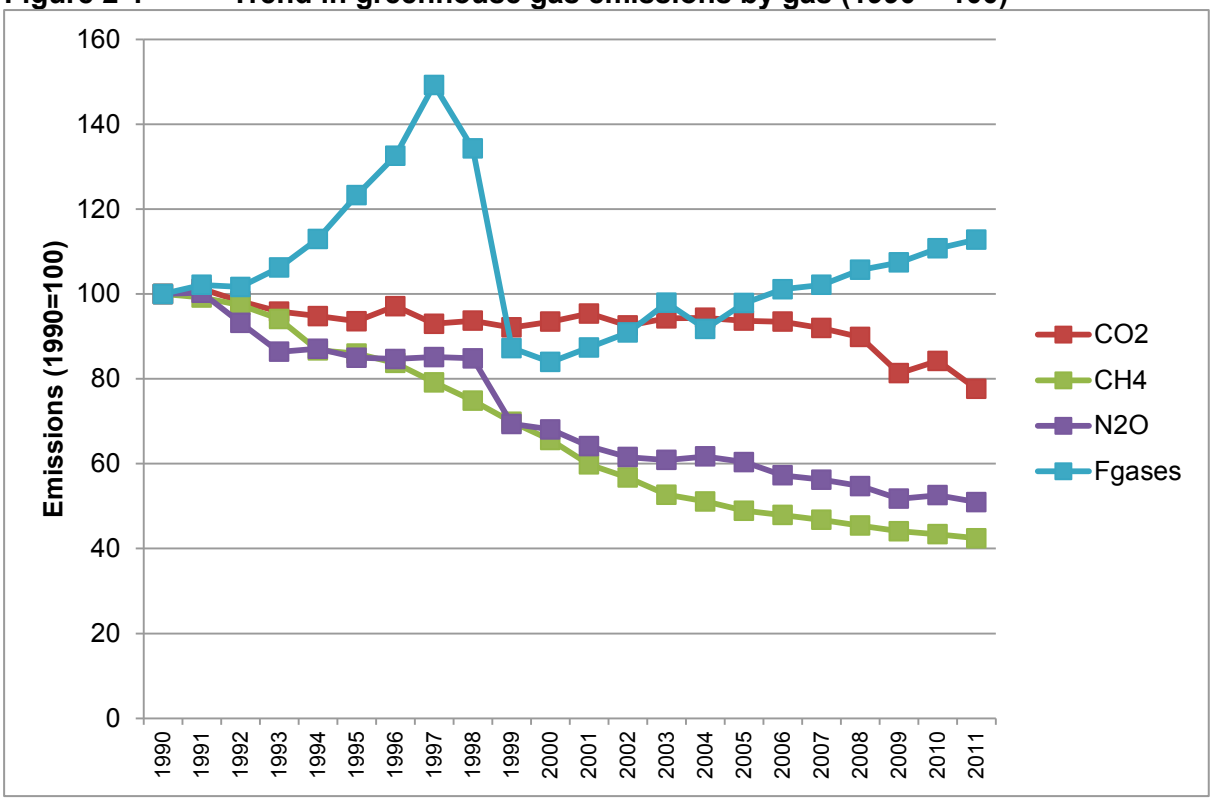
2.2 DESCRIPTION AND INTERPRETATION OF EMISSION TRENDS BY GAS

The largest contributor to global warming is CO_2 at 83.3% of the weighted emission in 2011 (see **Section 1.1.2.4** for information about weighted emissions). CH_4 contributes 7.6% and N_2O 6.3%. In spite of their high GWPs the contribution of halocarbons is small at around 2.8% of the total. This is because their mass emissions are very small. Overall the total weighted emission has fallen by 28.5% since 1990.

Table 2-2 UK Greenhouse Gas Emissions by Gas in 1990 and 2011

	CO_2	CH_4	N_2O	FGases	Total
Mt CO_2e					
1990	593.54	99.16	68.30	13.82	**774.81**
2011	460.69	42.06	34.81	15.59	**553.15**
% Share					
1990	76.60%	12.80%	8.81%	1.78%	**100%**
2011	83.28%	7.60%	6.29%	2.82%	**100%**

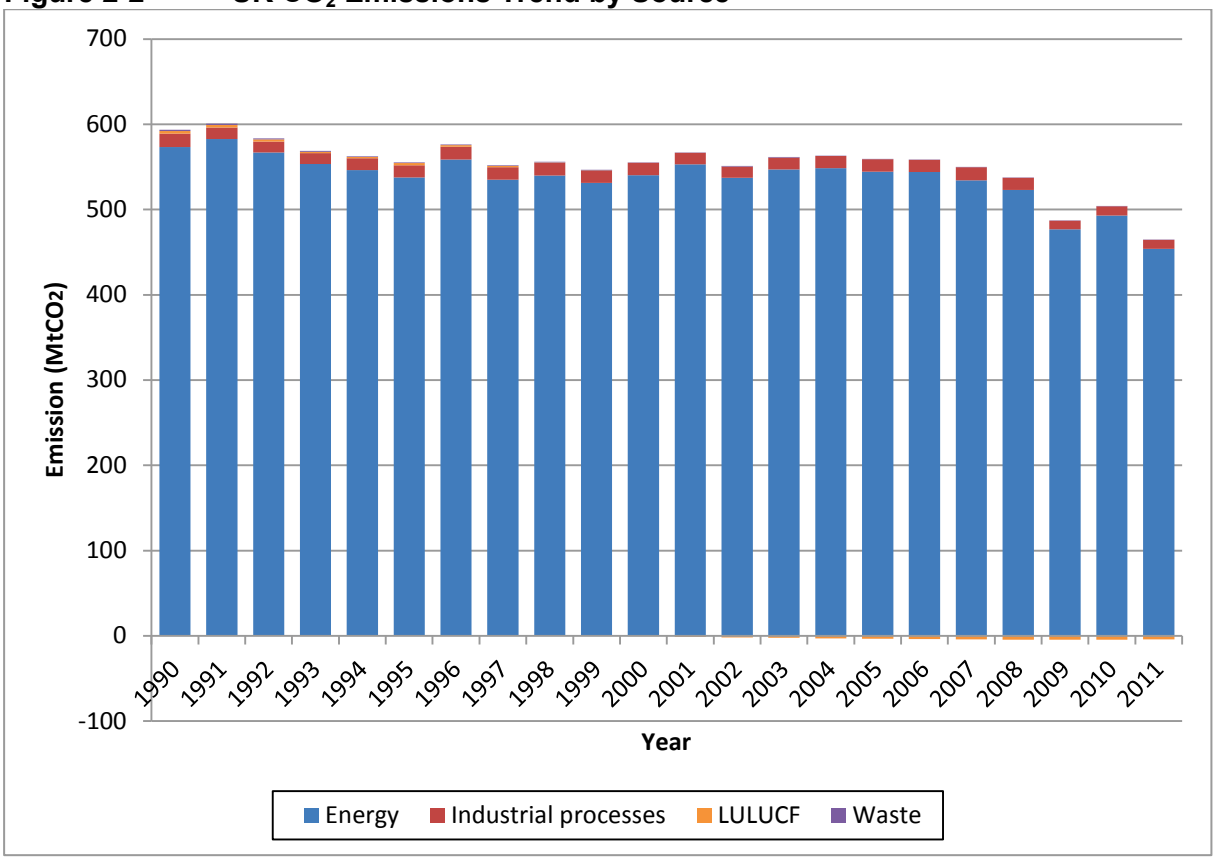
Figure 2-1 Trend in greenhouse gas emissions by gas (1990 = 100)



2.2.1 Carbon Dioxide

In 2011, CO_2 emissions were 460.7 Mt CO_2 equivalent, 22.4% below the 1990 level. The trend in CO_2 emissions is illustrated in Figure 2-2, which shows that the total emissions are dominated by the energy sector, which is the main driver for the declining trend in emission.

Figure 2-2 UK CO_2 Emissions Trend by Source



2.2.2 Methane

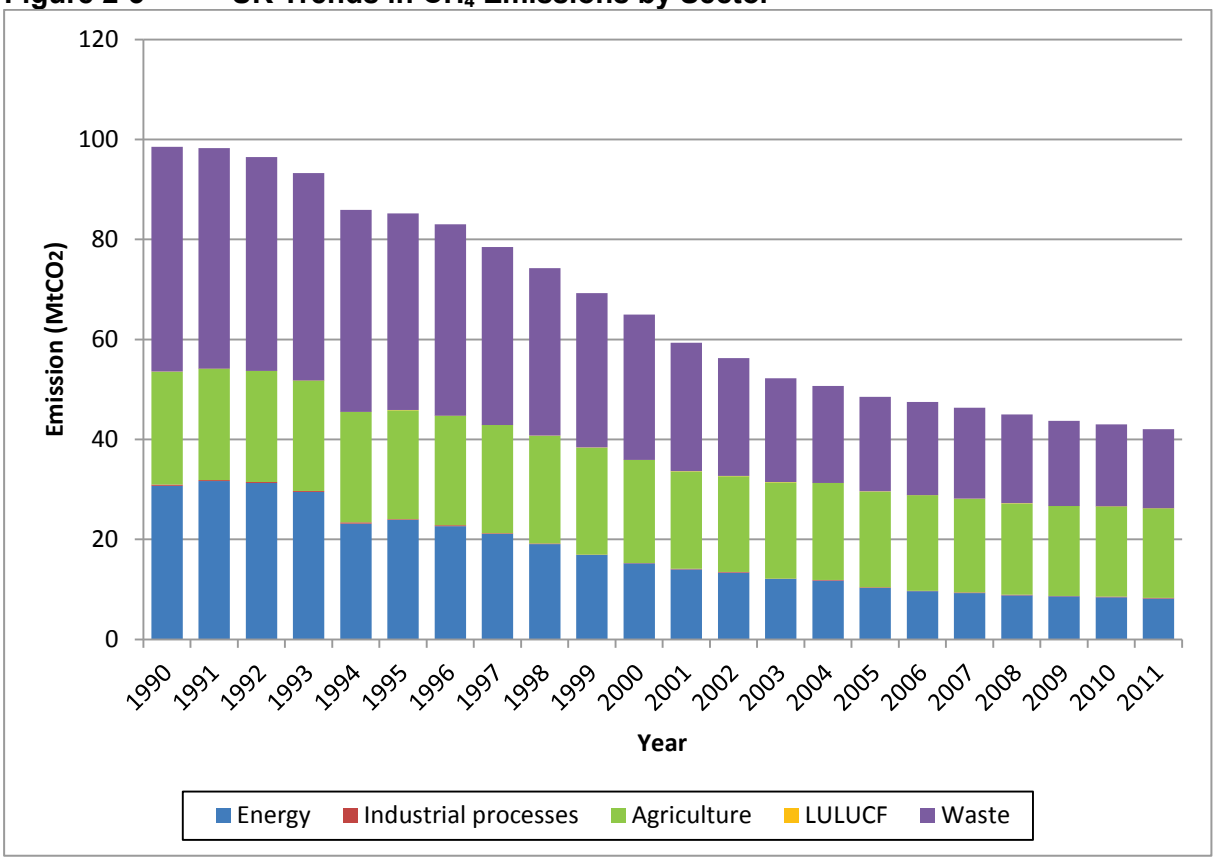
Figure 2-3 illustrates the trend in emissions of methane, broken down by source. Methane is the second most significant greenhouse gas in the UK after CO_2. In 2011, methane emissions were 42 Mt CO_2 equivalent.

The major sources of methane are agriculture, waste disposal, leakage from the gas distribution system and coal mining. Emissions from all these sources have declined since 1990, and the main reasons for these are:

- In the energy sector, reduced coal mining activity, and improvements to the gas distribution network have contributed to an overall decrease in emissions of 73.4% since 1990. Decreases in this sector have contributed 39.9% to the total decrease in methane emissions.
- Total emissions in the waste sector have decreased by 64.8% due to increased implementation of methane recovery systems at landfill sites. The reduction in emissions in this sector is responsible for 51.6% of the total decrease in methane emissions since 1990.
- Emissions from agriculture have decreased by 20.6% since 1990, following the trend of decreasing livestock numbers.

Since 1990, emissions of methane have decreased by 57.3%. Emissions from LULUCF and Industrial Processes are not significant sources of methane in comparison to the other sectors.

Figure 2-3 UK Trends in CH_4 Emissions by Sector

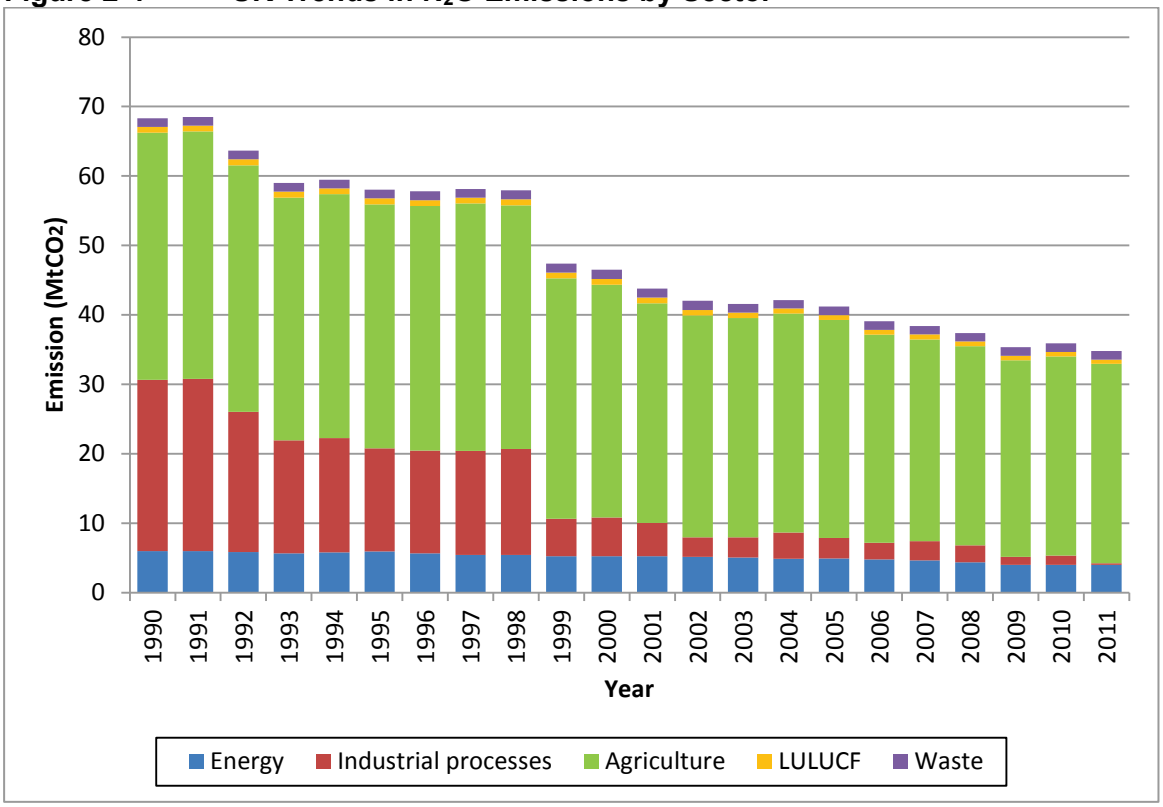


2.2.3 Nitrous Oxide

Figure 2-4 illustrates the trend in emissions of N_2O. The main anthropogenic sources are agriculture, transport, industrial processes, and coal combustion. In 2011, emissions of N_2O were 34.8 Mt CO_2 equivalent. Emissions have declined 49% since 1990, and the main reasons for this reduction are:

- The agriculture sector is a major source of N_2O emissions, contributing 82.6% to total emissions of N_2O. Emissions from this sector have decreased by 19.2% since 1990, mostly due to a decrease in emissions from sector 4D, agricultural soils, driven by a fall in synthetic fertiliser application.
- Although the total emission is dominated by agriculture, the trend in emissions across the time series is driven by a significant reduction in emissions from Industrial Processes. In 1990, nitric and adipic acid production were both significant sources of N_2O, contributing 36.1% to total N_2O emissions. In 2011, these sources accounted for only 0.6%. This has been a result of plant closures combined with the installation of abatement equipment at the adipic acid plant in 1998 (the effect of this can be seen in **Figure 2-4**). Emissions from Industrial Processes have decreased by 99.1% since 1990, contributing 73% to the total decline in N_2O emissions.
- Fuel combustion is also a significant N_2O source, with total emissions from the energy sector contributing 11.5% to total N_2O emissions in 2011. Emissions from this sector have decreased by 33.1% since 1990. The most significant sources within this sector are road transport, industrial combustion and power generation. Both industrial combustion and power generation have shown decreases in emissions since 1990. Road transport emissions increased steadily from 1990 to 1999 due to the increase in cars with 3-way catalysts in the fleet. From 2000 onwards, however, emissions from this source have started to decrease due to the improvements in catalyst technology in newer vehicles. Emissions in 2011 are now 28.1% lower than emissions in 1990.

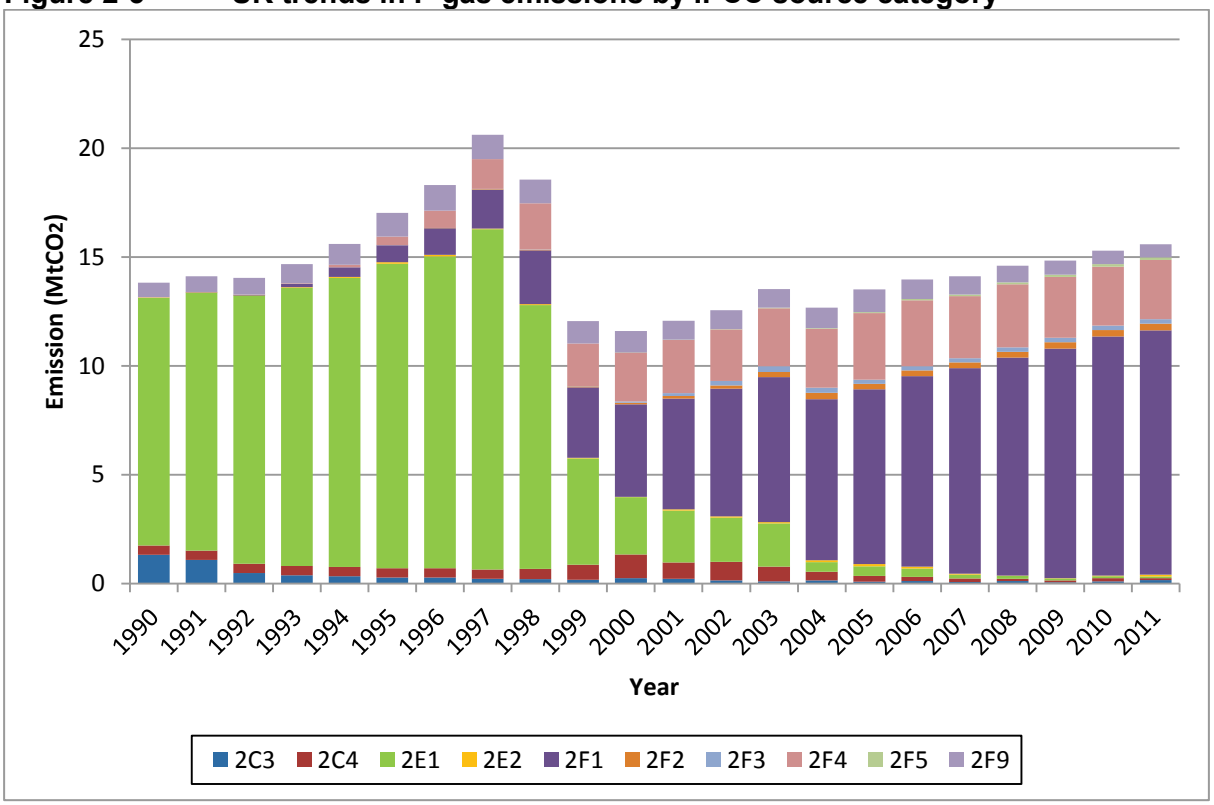
Figure 2-4 UK Trends in N_2O Emissions by Sector



2.2.4 Fluorinated-Gases

Emissions of the F-gases (HFCs, PFCs, and SF_6) totalled 15.6 Mt CO_2 equivalent in 2011. Since 1995 – the base year used for F-gases – the overall decrease in their emissions has been 8.5%, due mainly to the fall in emissions from F-gas manufacture, due to the installation of abatement equipment at two of the three manufacturers. Emissions from certain end use sectors, such as refrigeration, are continuing to grow.

Figure 2-5 UK trends in F-gas emissions by IPCC source category



The IPCC source categories referred to in Figure 2-5 are:

2C3: Aluminium Production
2C4: Aluminium and Magnesium Foudries
2E1: Production of Halocarbons and SF6
2F1: Refrigeration and Air Conditioning Equipment
2F2: Foam Blowing
2F3: Fire Extinguishers
2F4: Aerosols/Metered Dose Inhalers
2F5: Solvents
2F9: Other

2.3 DESCRIPTION AND INTERPRETATION OF EMISSION TRENDS BY CATEGORY

Table 2-3 below presents a summary of total GWP weighted emissions by sector.

Table 2-3 Total GWP weighted emissions by sector (Mt CO_2e)

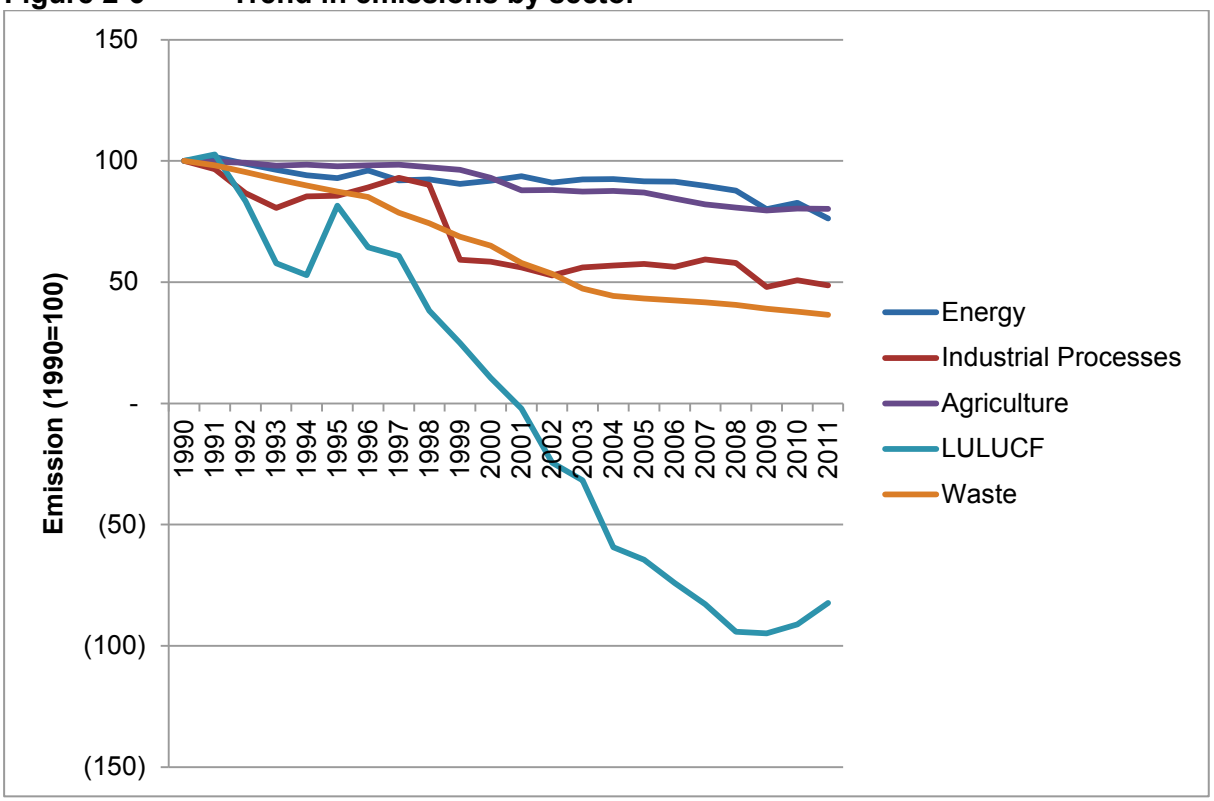
Year	Energy	Industrial Processes	Solvent and Other Product Use	Agriculture	LULUCF	Waste
1990	610.76	54.40	-	58.15	4.02	47.48
1991	620.38	52.58	-	57.92	4.13	46.60
1992	604.13	47.20	-	57.73	3.35	45.30
1993	588.59	43.89	-	57.05	2.33	43.90
1994	575.10	46.42	-	57.25	2.13	42.67
1995	567.38	46.59	-	56.87	3.28	41.48
1996	587.04	48.44	-	57.12	2.59	40.42
1997	561.47	50.61	-	57.22	2.45	37.34
1998	564.28	49.00	-	56.61	1.54	35.30
1999	553.37	32.25	-	56.01	1.00	32.62
2000	560.67	31.81	-	54.09	0.42	30.91
2001	572.18	30.51	-	51.12	-0.08	27.49
2002	555.87	28.67	-	51.17	-0.99	25.38
2003	564.19	30.53	-	50.81	-1.28	22.49
2004	565.09	30.93	-	50.93	-2.38	21.03
2005	559.57	31.30	-	50.55	-2.59	20.52
2006	558.40	30.68	-	49.10	-2.98	20.15
2007	548.13	32.33	-	47.77	-3.33	19.81
2008	536.22	31.48	-	46.99	-3.79	19.29
2009	489.48	26.11	-	46.25	-3.82	18.54
2010	505.45	27.65	-	46.73	-3.67	17.96
2011	465.95	26.47	-	46.67	-3.31	17.36

Total emissions are dominated by the energy sector in both 1990 and 2011, contributing 79% to total net emissions in 1990 and 84% in 2011. Emissions form all sectors have declined between 1990 and 2011, with the largest decline in percentage terms from the LULUCF sector, which has gone from a net source to a net sink. In absolute terms, the largest decline is in the energy sector.

Table 2-4 Emissions by sector in 1990 and 2011, the emissions trend and share of the total

Sector	Emissions (Mt CO_2e)		Trend	Share	
	1990	2011	1990-2011	1990	2011
Energy	610.76	465.95	-24%	79%	84%
Industrial Processes	54.40	26.47	-51%	7%	5%
Solvent and Other Product Use	-	-	N/A	0%	0%
Agriculture	58.15	46.67	-20%	8%	8%
LULUCF	4.02	-3.31	-182%	1%	-1%
Waste	47.48	17.36	-63%	6%	3%
Grand Total	774.81	553.15	-29%	100%	100%

Figure 2-6 Trend in emissions by sector



2.3.1 Energy

In 2011 emissions in the energy sector accounted for 84% of total net direct greenhouse gas emissions and have declined by 24% since 1990.

For CO_2; 98% of total net emissions came from this sector in 2011. Energy industries (category 1A1) were responsible for 37% of the sector's CO_2 emissions in 2011. There has been an overall decline in emissions from this sector of 24% since 1990. After the privatisation of the power industry in 1990, there was a strong move away from coal and oil generation towards use of gas.

Overall, between 1990 and 2011, there has been a 14% increase in the amount of electricity generated but a 24% decrease in CO_2 emissions from Power stations (1A1a). There are several reasons. Firstly, the shift towards use of CCGT stations rather than conventional steam stations burning coal or oil – CCGT stations operate at a higher thermal efficiency, for example in 2011 they operated at 48.5% efficiency, whilst coal-fired stations operated at 35.7% efficiency.[1] Secondly, the calorific value of natural gas per unit mass carbon is higher than that of coal and oil. Thirdly, a slight increase in electricity generated from non-fossil fuel energy sources, due to increased use of wastes and renewable energy sources, which in 2011 including nuclear energy provided 29% of UK electricity generation.

Emissions of from category 1A2 – Manufacturing Industries and Construction contributed 12% to overall net CO_2 emissions in the UK in 2011. Since 1990, these emissions have declined by 35%, mostly as a result of a decline in the emissions from the Iron and steel

[1] Plant loads, demand and efficiency, Table 5.10, DECC (2012)

industry. This sector has seen a significant decrease in coke, coal and fuel oil usage, with an increase occurring in the emissions from combustion of natural gas.

Emissions of CO_2 from 1A3 (Transport) are dominated by road transport (1A3b), which in 2011 contributed 92% to the total emissions from transport. Emissions from road transport peaked in 2007 at 11% above 1990 levels. Since 2007 CO_2 emissions from road transport have declined steadily to only 1% above 1990 levels. This may be as a result of recent economic downturn. Emissions of CO_2 from domestic aviation increased by 71% between 1990 and 2005, but have since shown a decrease of 28% since 2005 despite an increase in the total number of km flown. This is because of a move to use more fuel efficient aeroplanes in 2006.

Emissions of CO2 in the domestic sector (1A4b) account for 76% of CO2 emissions in 1A4. These emissions have changed little over the whole period 1990-2011 although can be very dependent on annual temperatures with a large variation in emissions, particularly in the later years. Fuel consumption data since 1990 indicates a general trend in fuel switching in these sectors, away from more carbon-intensive fuels such as coal, coke, fuel oil and gas oil, towards burning oil and natural gas. This shift has partly been driven by fuel prices but also through the growth of the UK gas supply network (most notably in Northern Ireland).

Methane emissions in the energy sector are mostly from fugitive emissions (1B). In 1990, 64% of these emissions came from the production of solid fuels, however these emissions have decreased by 89% and now make up just 28% of fugitive CH_4 emissions. Fugitive emissions from oil and gas operations have also decreased over this period, by 51%.

The energy sector accounted for 12% of total N_2O emissions in the UK during 2011. Of this, 35%, arose from energy industries (1A1). Within this category, emissions from public electricity production have shown a 44% decrease, whilst emissions from petroleum refining have increased by 35%. Emissions from 1A1c (Manufacture of Solid Fuels and Other Energy Industries) have increased by 10% between 1990 and 2011. N_2O emissions from the energy sector have decreased overall by 33% since 1990. Over this period the use of coal has decreased and the use of natural gas increased.

The other major contribution towards N_2O emissions within the energy sector is the transport sector (1A3) (24%). Between 1990 and 1995, emissions increased by 41% due to the increasing numbers of petrol driven cars fitted with early generation three-way catalysts. These are used to reduce emissions of nitrogen oxides, carbon monoxide and non-methane volatile organic compounds however; nitrous oxide is produced as a by-product. Since then, emission factors have been declining with successive Euro standards, presumably due to better catalyst formulations as well as reductions in fuel sulphur content. The overall change in the N_2O emissions from the transport sector between 1990 and 2011 is a 24%.

2.3.2 Industrial Processes

Emissions of direct Greenhouse gases within this sector have decreased by 51% since 1990. For 2011, 40% of emissions in this sector were of CO_2, although this made up only 2% of all CO_2 emissions. Only a small quantities of CH4 and N2O come from this sector, whilst 100% of F-gases come from industrial processes.

Between 1990 and 2011, emissions of N_2O from this sector declined by an estimated 99% due to reductions in emissions from adipic acid manufacture (a feedstock for nylon) and nitric acid production. N_2O emissions from nitric acid manufacture show a fall in 1999 due to the

installation of an abatement system at one of the plants and another fall in 2011 due to installation of abatement in the remaining plants. Emissions from adipic acid manufacture were reduced significantly from 1998 onwards due to the retrofitting of an emissions abatement system to the only adipic acid plant in the UK, which subsequently closed in April 2009.

Since 1990, emissions of HFCs have increased by 29%. The largest contribution to this sector in 2011 arises from category 2F1 – refrigeration and air conditioning equipment. In 2011, these contributed 77% to the overall emissions of HFCs. Emissions from this category arise due to leakage from refrigeration and air conditioning equipment during its manufacture and lifetime. Emissions from aerosols contribute the next largest percentage (19%) to overall HFC emissions. In this category, it is assumed that all the fluid is emitted in the year of manufacture. This category contains mainly industrial aerosols and also metered dose inhalers (MDI). Emissions from manufacture of HFCs and HCFCs have decreased by 99% since 1990, due to plant closures and the installation of abatement equipment.

PFC emissions have declined by 77% since 1990. The main source of PFC emissions is aluminium production. During the process of aluminium smelting, PFC is formed as a by-product. The emissions are caused by the anode effect, which occurs when alumina concentrations become too low in the smelter. This can cause very high electrical current and decomposition of the salt – fluorine bath. The fluorine released then reacts with the carbon anode to create CF_4 and C_2F_6. Since 1990, emissions arising from aluminium production have shown an 88% decrease due to significant improvements in process control and an increase in the rate of aluminium recycling.

The use of SF_6 in magnesium foundries contributed 12% towards total SF_6 emissions in 2011, and total emissions have decreased by 83%. Emissions from 2F9 – Other contributed 88% towards emissions, which includes emissions from electrical insulation. Emissions arise during the manufacture and filling of circuit breakers and from leakage and maintenance during the equipment lifetime. It also includes emissions from applications in the electronics industry and sports shoes.

2.3.3 Solvent and other product use

No direct GHG emissions are reported in this category.

2.3.4 Agriculture

Direct GHG emissions in 2011 were 38% CH_4 and 62% N_2O. Total direct GHG emissions decreased by 20% between 1990 and 2011. CH_4 emissions have declined by 21%, driven mostly by a decline in emissions from enteric fermentation from cattle due to decreased cattle numbers. N_2O emissions have decreased by 19%, which has been driven by both a decline in animal numbers and a decrease in synthetic fertiliser application.

2.3.5 Land use, land use change and forestry

The UK has moved from being a net source of CO_2 from LULUCF activities in 1990 to a net sink for all years since 2000. Total emissions of direct greenhouse gases from the LULUCF sector decreased by 180% between 1990 and 2011. The size of the net sink has decreased by 10% since 2010. The land use categories which have the greatest effect on the net LULUCF emissions / removals are forest land (a net sink), cropland (a net source) and grassland. Forestland is currently a decreasing sink due to a lowering of the average age of trees as a consequence of historically low rates of aforestation during the 1990s. Emissions

from cropland have decreased by 28% since 1990 (4% since 2010). Net removals from grassland have increased by 33% since 1990, although the size of the sink decreased by 1% since 2010.
Compared to CO_2, emissions of CH_4 and N_2O are relatively low in this sector. Methane emissions from the forestry, cropland, grassland and settlements categories have increased by 18% since 1990 (16% increase since 2010). Emissions of nitrous oxide have decreased by 30% since 1990 (4 % decrease since 2010).

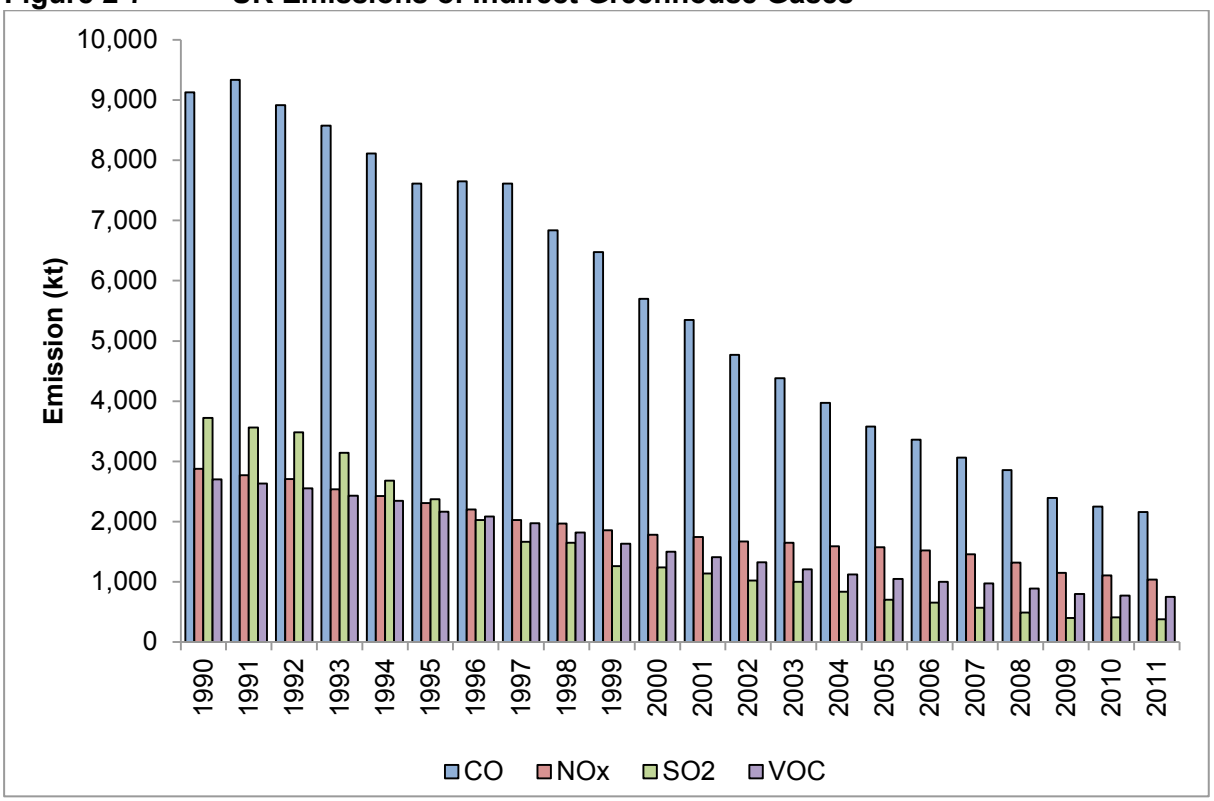
2.3.6 Waste

Total emissions from the waste sector have declined by 63% since 1990. This is mostly driven by a decline in methane emissions from landfill. Emissions estimates from landfill are derived from the amount of biodegradable waste disposed of to landfill and are based on a model of the kinetics of anaerobic digestion involving four classifications of landfill site. The model also accounts for the effects of methane recovery, utilisation and flaring. Since 1990, methane emissions from landfill have declined by 67% due to the implementation of methane recovery systems. This trend is likely to continue as all new landfill sites are required to have these systems and many existing sites may have systems retrofitted.

2.4 EMISSION TRENDS FOR INDIRECT GREENHOUSE GASES AND SO_2

The indirect greenhouse gases in the UK consist of Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Non-Methane Volatile Organic Compounds (NMVOC) and Sulphur dioxide (SO_2). Of these, NO_x, CO and NMVOC can increase tropospheric ozone concentration and hence radiative forcing. Sulphur dioxide contributes to aerosol formation in the atmosphere. This is believed to have a negative net radiative forcing effect, tending to cool the surface. Emission trends for the indirect greenhouse gases are shown in **Table 2-4**.

Figure 2-7 UK Emissions of Indirect Greenhouse Gases



2.4.1 Carbon Monoxide

In 2011, the total emissions of CO were 2,015 Gg, and since 1990, emissions have decreased by 76%.

Emissions of carbon monoxide from the energy sector contributed 93% to overall UK CO emissions in 2011. Of this, 40% of emissions occur from transport (1A3). Since 1990, emissions from 1A3 have declined by 87%, which is mainly because of the increased use of three way catalysts, although a proportion is a consequence of fuel switching in moving from petrol to diesel cars.

Emissions from sector 1A2 contributed 31% to overall emissions of CO in 2011. Emissions from within this category mostly come biomass combustion and petrol use in off-road vehicles within the Manufacturing, industry and combustion sector.

2.4.2 Nitrogen Oxides

In 2011, total emissions of NO_x were 1,037 Gg, and since 1990, emissions have decreased by 64%.

Over 99% of NO_x emissions in the UK came from the energy sector in 2011. Since 1990 emissions from this sector have decreased by 64%, mostly as a result of abatement measures on power stations, three-way catalysts fitted to cars and stricter emission regulations on trucks. The main source of NO_x emissions is transport: in 2011, emissions from transport contributed 42% to the total emissions of NO_x in the UK, with 33% arising from road transport (1A3b). From 1970, emissions from transport increased (especially during the 1980s) and reached a peak in 1989. This reduction in emissions is due to the requirement since the early 1990s for new petrol cars to be fitted with three way catalysts and the further

tightening up of emission standards on these and all types of new diesel vehicles over the last decade.

Emissions from the energy industries (1A1) contributed 31% to total NO_x emissions in the UK during 2011. Between 1990 and 2011, emissions from this sector decreased by 63%. The main reason for this was a decrease in emissions from public electricity and heat production (1A1a) of 69%. Since 1998 the electricity generators adopted a programme of progressively fitting low NO_x burners to their 500 MWe coal fired units. Since 1990, further changes in the electricity supply industry such as the increased use of nuclear generation and the introduction of CCGT plant have resulted in additional reduction in NO_x emissions.

Emissions from Manufacturing, Industry and Construction (1A2) have fallen by 56% since 1990. In 2011, emissions from this sector contributed 17% to overall emissions of NO_x. Over this period, the industrial sector has seen a move away from the use of coal, coke and fuel oil towards natural gas and gas oil usage.

2.4.3 Sulphur Dioxide

In 2011, total emissions of SO_2 were 382 Gg, and since 1990, emissions have decreased by 90%.

96% of emissions of sulphur dioxide came from the energy sector in 2011. 64% of these emissions arose from energy industries (1A1). A majority of these emissions are from the public electricity and heat production category (1A1a). Since 1990, emissions from power stations have declined by 94%. This decline has been due to the increase in the proportion of electricity generated CCGT stations and other gas fired plant. CCGTs run on natural gas and are more efficient than conventional coal and oil stations and have negligible SO_2 emissions.

Emissions from Manufacturing, Industry and Construction (1A2) were responsible for 19% of UK emissions of SO_2 in 2011. Since 1990, emissions from this category have declined by 84%. This decline is due to the reduction in the use of coal and oil in favour of natural gas, and also some improvement in energy efficiency.

2.4.4 Non Methane Volatile Organic Compounds

In 2011, total emissions of NMVOCs were 753 Gg, and since 1990, overall emissions have decreased by 72%.

Emissions from the Solvents and Other Product Use sector contribute 46% to overall emissions of NMVOC in 2011, and since 1990 emissions have declined by 48%. The largest source of emissions within the solvents sector is category 3D (solvent and other product use: other), contributing 70% of NMVOC emissions in this sector.

35% of non-methane volatile organic compound emissions came from the energy sector in 2011. Of these, the largest contribution arises from the fugitive emissions of oil and natural gas (1B2), which contributed 19% towards the overall UK emissions of NMVOCs in 2011. This includes emissions from gas leakage, which comprise around 13% of the total for the energy sector. Remaining emissions arise from oil transportation, refining, storage and offshore.

Emissions from transport (1A3) contribute 7% to overall emissions of NMVOC in the UK in 2011. Since 1990, emissions from this sector have decreased by 94% due to the increased use of three way catalysts on petrol cars.

Emissions from the industrial processes sector contributed 15% to overall UK emissions of NMVOCs. The majority of emissions within this category come from the food and drink sector. Emissions also arise from the chemical industry.

2.5 EMISSION TRENDS FROM KP LULUCF ACTIVITIES

Figure 2-8 shows net emissions/removals from afforestation, reforestation and deforestation activities (Article 3.3). These activities were a net source of emissions in 1990, becoming a net sink from 1996 onwards.

Figure 2-9 shows the net emissions and removals of greenhouse gases from forest management activities (Article 3.4). In accordance with the Annex to Decision 16/CMP.1, credits from Forest Management are capped in the first commitment period. For the UK the cap is a relatively modest 0.37 MtC (1.36 $MtCO_2$) per year, or 6.78 $MtCO_2$ for the whole commitment period.

The main driver of the emission and removal trends for KP-LULUCF before the application of the forest management cap is the degree of forest planting achieved between the 1950s and the 1980s, followed by a period of reduced planting rates. As these forest stands have reached maturity and are now being harvested, removal of carbon dioxide is reduced.

Figure 2-8 Article 3.3 Emissions and Removals, by gas and by activity

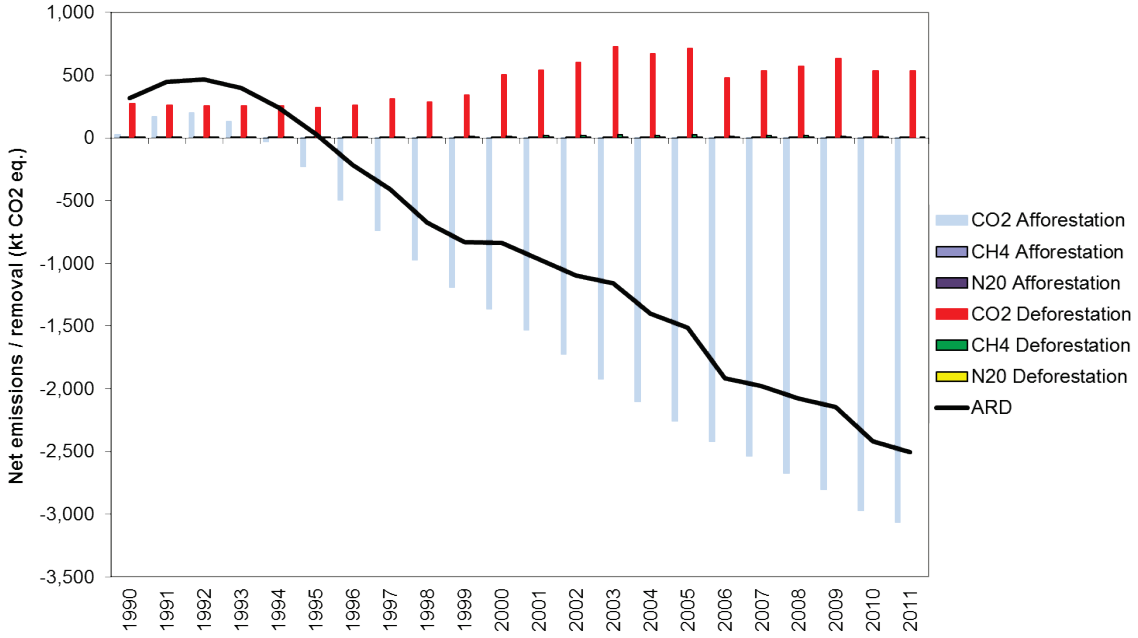
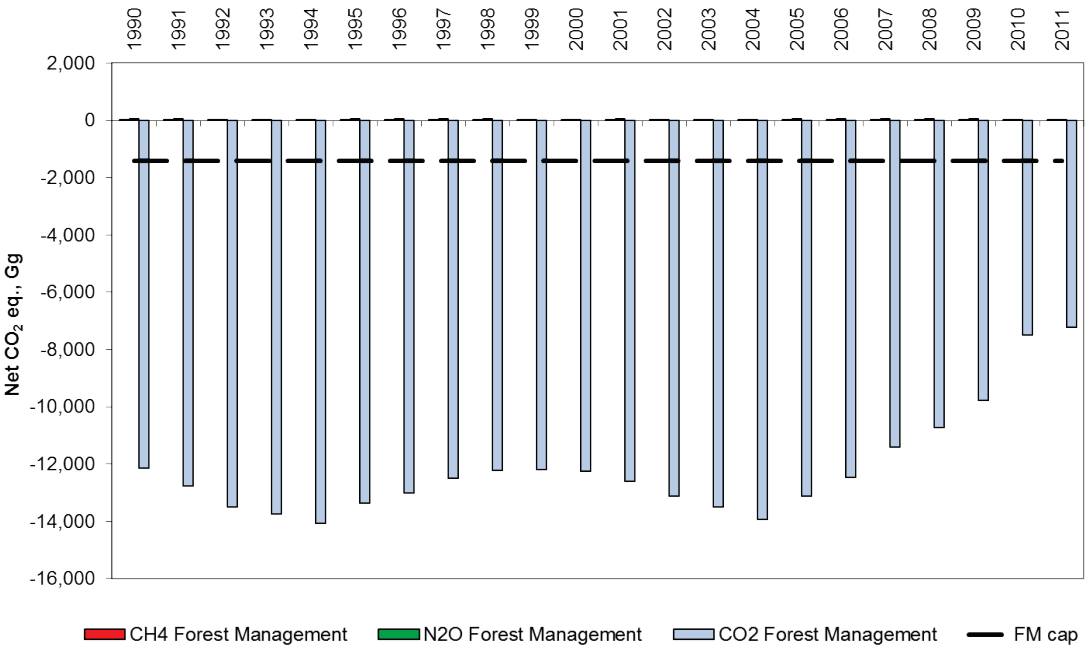


Figure 2-9 Article 3.4 Emissions and removals, by gas



3 Energy (CRF Sector 1)

3.1 OVERVIEW OF SECTOR

IPCC Categories Included	1A: Fuel Combustion 1B: Fugitive Emissions from Fuels
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-oil, CO_2
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Mobile combustion-Road vehicles, CO_2 Mobile combustion-Road vehicles, N_2O Stationary combustion-coal, CO_2 Stationary combustion-gas, CO_2 Stationary combustion-oil, CO_2
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	All relevant UK Overseas Territories and Crown Dependencies emissions included within category totals within CRF submission – UK EFs used. Tables of total fuel use can be found in **Annex 3.9**.
Completeness	Only known omission is emissions from multilateral operations (a memo item) for which data are not available. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	**1A1a:** Improved accuracy of carbon emission factors for MSW to reflect UK waste compositional survey data and changes in MSW composition over the time series. **1A2f**: Improved completeness and accuracy of estimates from petrochemical / industrial use of process gases derived from NGLs and OPG. **1A3d:** Addition of vessel movements between UK and Overseas Territories. **1A4c:** Addition of fishing activities outside UK waters.

In 2011 emissions in the energy sector accounted for 84% of total net direct greenhouse gas emissions. Within this category the largest contributions arise from 1A1 (energy industries), while 1A3 (transport), 1A4 (other sectors) and 1A2 (Manufacturing, Industry and construction) also have a significant impact on the emissions of this sector. Energy sector emissions have declined by 24% since 1990, as shown in **Figure 3-2**, primarily due to fuel switching to less carbon-intensive energy sources (e.g. coal to gas in the power sector) and reduced energy intensity of the economy

Figure 3-1 Breakdown of total GHG emissions in Energy sector in 2011

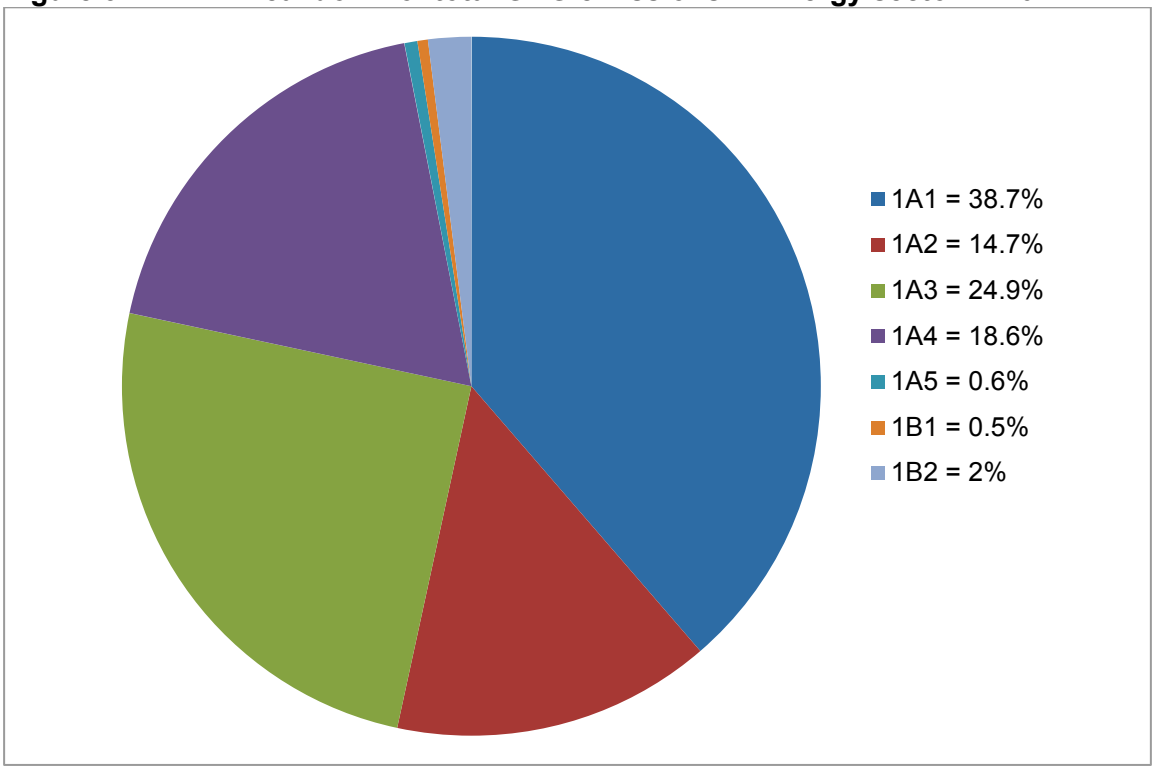
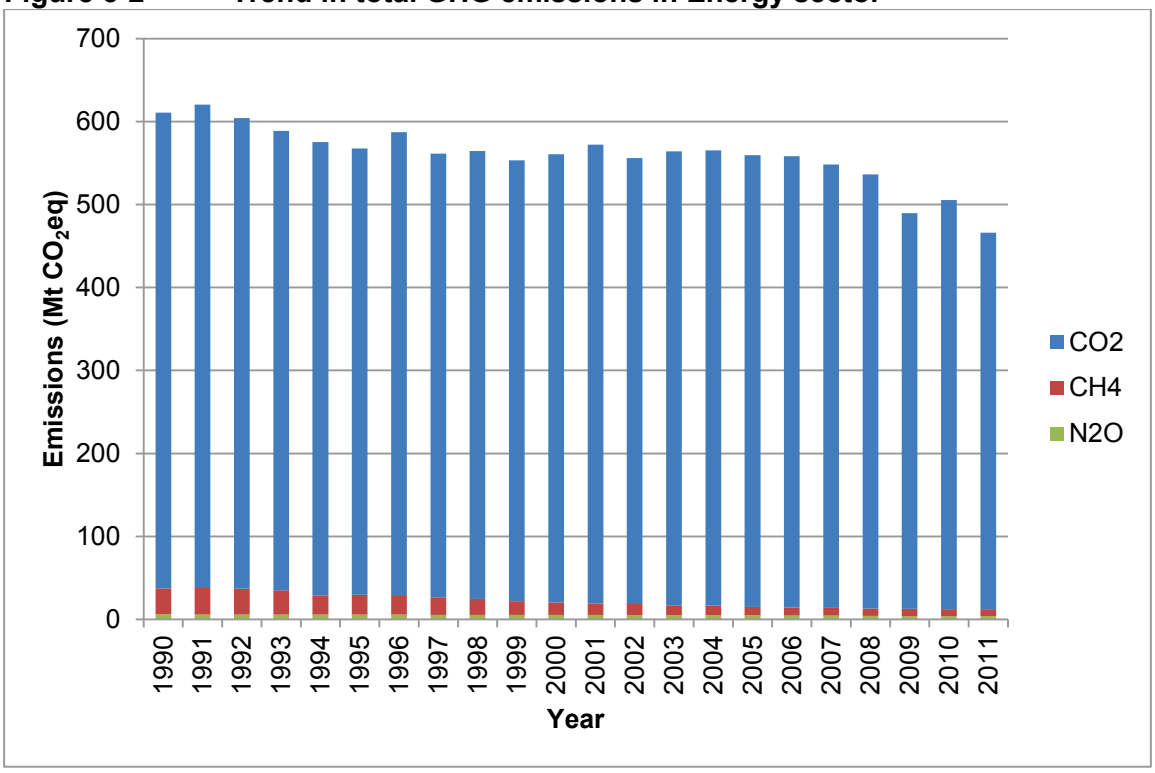


Figure 3-2 Trend in total GHG emissions in Energy sector



3.2 FUEL COMBUSTION (CRF 1.A)

3.2.1 Fuel Use Statistics

The main source of energy consumption data used in the UK inventory is the Digest of UK Energy Statistics (DECC, 2012), hereafter referred to as DUKES. This annual publication gives detailed sectoral energy consumption broken down by fuel type, and covering the entire time period covered by the inventory. In many cases, these data are used directly in the inventory without modification. However, there are instances where the activity data used in the inventory are not based directly on DUKES data, where alternative data sources provide supplementary data to inform energy use and emission estimates, including:

- Where a greater level of detail is required in the reporting of emissions than can be provided solely from DUKES data (e.g. to estimate fuel use and emissions for (i) mobile and (ii) stationary combustion sources separately in industrial, commercial and agricultural source categories);
- Where other data sources provide additional evidence that supports modifications to the DUKES data (for example, changes to the data for fuel oil usage in CRF category 1A1a).

The rationale for those modifications or deviations from DUKES data that are made, and the sources of alternate data are discussed in the sections detailing methodology for each CRF source category that follow **Section 3**. A summary of all of the modifications is given in **Annex 3, Section A3.3**.

The modifications described above involve changes to the sector-level estimates of fuel use used in the UK inventory, when compared with the original source data from DUKES. As a general rule, the overall demand for each fuel in the UK inventory is kept consistent with the overall demand for that fuel in DUKES; the inventory agency approach is such that in almost all cases, any modifications to the sector allocation of DUKES data is matched by an equal and opposite allocation change in another sector, to ensure a zero net change in fuel demand relative to DUKES. **Annex 3, Section A3.3** includes a series of tables that demonstrate this consistency between the UK inventory and DUKES.

There are some exceptions to the general rule of consistency with DUKES, for petroleum coke and for OPG, where other statistical evidence indicates that the energy balance data for fuel combustion sources is incorrect, and where re-allocations of fuel use from the “non-energy use” lines in DUKES are made by the inventory agency. These exceptions are described in **Section 3.2.9** (section on 1A1) and shown in tabulated form in **Annex 3, Section A3.3**.

Apart from DUKES, the main other data source used for fuel use estimates in the inventory is the installation-level data available for processes covered by the EU Emissions Trading System (DECC, 2012b), which has been analysed and compared with the data from DUKES. Further details of the analysis of EU ETS and use of the data within the UK GHG inventory are given in **Annex 9**. Further fuel consumption data are taken from the EEMS data set (DECC Offshore Inspectorate, 2012) and from data supplied by the UK Mineral Products Association (MPA, 2012), and from the UK solid fuel supply sector (Roberts, 2012). These are used to modify fuel use and emission estimates for 1A1c, 1A2f, and 1A4b respectively, and are described more fully in the sections below that deal with those source categories.

Fuel use estimates for transport sources also rely upon data taken from DUKES, with some further detail provided from other sources . Details are given in **Section 3.2.11**.

3.2.2 Comparison of Sectoral and Reference approaches

This comparison is documented and described in **Annex 4**.

Summary Table 7B of the IPCC Guidelines[18] includes the IPCC Reference Inventory total for CO_2. This is a top-down inventory calculated from national statistics on production, imports, exports and stock changes of fossil fuels. All other Sectoral Tables report emissions of pollutants estimated using a bottom-up approach with emissions estimated from activity statistics (mostly fuel consumption) in the various economic sectors and processes.

In principle the IPCC Reference Total can be compared with the IPCC Table 1A Total. The Reference Approach typically produces UK CO_2 emission estimates that are between 1% lower to 2% higher than the more detailed Sectoral Approach, due to statistical differences between production-side and demand-side fuel estimates within national energy statistics, and the more aggregated approach to applying emission factors to activity data across fuel types in the Reference Approach. Reasons for the differences between the two estimates are discussed in **Annex 4**.

Over the period (1990 to 2011), emissions estimated by the Reference Approach have fallen by 19% compared with 14% for the Sectoral Approach. A more detailed discussion of the reasons for this difference is given in **Annex 4**.

3.2.3 International Bunker Fuels (memo item)

International bunker emissions (international aviation and shipping) are not included in the national total but are reported separately. A recent bottom-up method has been used to estimate domestic inland waterway emissions and this has led to a re-allocation of marine fuels and hence emissions between domestic and international bunkers. The new method has slightly decreased the allocation of total shipping emissions to international bunkers. In 2011, the shipping emission contributed 23% to total bunker emissions, with aviation contributing the remaining 77%. From 1990-2006, estimated emissions from international aviation more than doubled, but have been slowly declining since 2006.

These estimates are consistent with the revised Tier 3 method now adopted for aviation and described in **Section 3.2.11.2.1** and the revised Tier 2 method now adopted for shipping described in **Section 3.2.11.2.6.**

In response to feedback from the Expert Review Team, the inventory agency has confirmed with the UK national energy statistics team at DECC that the UK allocations of bunker fuels reported within DUKES are consistent with the data submitted to EUROSTAT and the IEA across the full time-series. Note, however, that the UK inventory memo item estimates for international shipping deviate from the reported DUKES (and IEA/EUROSTAT) data due to reallocation of some of the bunker fuels to military aviation and shipping based on data from the Defence Fuels Group of the MoD; these emissions are included in national inventory estimates and not in the International bunkers estimate.

Furthermore, the revisions to the shipping and inland waterways methodology described above have led to changes in the domestic/international split in fuel use allocation for marine

[18] http://www.ipcc-nggip.iges.or.jp/public/gl/guidelin/tab3.pdf

fuels from the allocations in the national energy statistics (DUKES) and submissions to IEA/EUROSTAT.

3.2.4 Biomass

Combustion of biomass is included in the UK energy statistics and also in the UK inventory. The inventory considers the use of such fuels in all subsectors of CRF 1A, although biomass is currently only used in a limited number of sectors, including 1A1a, 1A2f, and 1A4b. Greenhouse gas emissions including carbon dioxide are estimated for these fuels and presented in the relevant sections of the CRF. Emissions of nitrous oxide and methane from biomass combustion are included within the UK inventory totals. The carbon dioxide emissions from biomass are, however, not added to the total UK emissions from fuel combustion and are instead recorded as a memo item.

3.2.5 Wastes and Waste-Derived Fuels

As with biomass, wastes used as fuels are included in both the UK energy statistics and in the UK inventory and emissions reported in the relevant sections of the CRF.

Small-scale use of wastes as fuels may not be reported completely within national statistics where wastes are disposed of in-situ by means of use as a fuel, and in these instances the UK GHG inventory data may be incomplete also. The inventory agency does make estimates for some known sources that are not reported in national statistics, for example the use of process wastes as fuel by the chemical industry are included in estimates within source category 2B5. However, these estimates are subject to high uncertainty due to a lack of source data and there may be other sections of small-scale industry that burn waste to raise heat for which no estimates are currently made in the UK inventory.

Other sources not currently estimated within the UK inventory include household use of domestic wastes for heating, for which there are no national statistics and the incidence of this activity is considered to be very low in the UK and therefore it is assumed that this would be a very insignificant source of GHG emissions. In addition, a high proportion of wastes burnt both in industry and in households is likely to be predominantly biomass-based, e.g. wood, paper, food waste, etc., and so any CO_2 emissions would not need to be reported in UK inventory totals anyway.

3.2.6 Feedstock and Non-Energy Use of Fuels

The UK inventory estimates for many source sectors include a component of emissions that are derived from fossil fuels that according the UK energy balance (DECC, 2012) are allocated to “non-energy use”. Within each of the DUKES commodity balance tables, the energy statistics include sector-specific fuel use estimates, and also an annual estimate for fuels that are not directly used as an energy source. These estimates of non-energy use in DUKES are based on the annual returns to DECC from energy suppliers, supplemented by surveys of fuel users; the information provided to DECC typically indicates the allocation of fossil fuels to be used as feedstock in chemical and petrochemical production processes.

In many cases the energy statistics allocate fuels to non-energy use that are used in chemical and petrochemical production processes where either:

- fossil carbon-containing off-gases are used for combustion in facility boilers; or

- products containing the “stored” carbon are subsequently used / partly combusted / disposed and degraded with some proportion of the “stored carbon” in products ultimately emitted to atmosphere.

In other instances, the allocation of fuels to “non-energy use” in the UK energy balance is contrary to other statistical evidence from industry or surveys that the inventory agency has access to in the compilation of the national inventory. For example, in the UK the allocation of petroleum coke to combustion sources in the energy balance are missing for many years in the time series, whereas evidence from environmental reporting and research indicates that several industries use petroleum coke directly as a fuel or process input (e.g. cement kilns, power stations, SSF manufacture).

The inventory agency generates annual estimates to account for all of these emission sources, effectively re-allocating a share of the DUKES non-energy use to either combustion or process emission sources in the inventory. The evidence that the inventory agency uses to make these estimates includes:

- annual reporting by plant operators (e.g. EU ETS returns include data on the use of process off-gases in the chemical and petrochemical production sector);
- periodic surveys or research by trade associations / research organisations / environmental regulators, such as to assess the fate of coal tars and benzoles, petroleum coke or waste oils or the impact of regulations on solvents, waste, product design and use;
- information on the estimated split of stored:emitted carbon from feedstock chemicals in literature sources, including other country NIRs, where UK-specific information is not available.

3.2.6.1 Inventory Compilation Methods for Feedstock / NEU of Fuels

The estimation methods are described within individual sections of the NIR, but are summarised here. The general approach adopted in the UK GHG inventory is to assume that emissions from these non-energy uses of fuels are zero (i.e. the carbon is assumed to be sequestered as products), except for cases where emissions can be identified and emission estimates included in the inventory.

The UK inventory agency conducts periodic studies into the fate of fuels reported as non-energy use, in order to assess the levels of stored carbon and carbon emitted for different fuels over the time series. These detailed studies are supplemented through annual data gathering and consultation with stakeholders to maintain an accurate representation of the emitted and stored carbon in the inventory.

Many of the assumptions and estimates for individual sources are based on a review conducted in 2007(Passant et al, 2007) which included research into UK-specific activities and data sources as well as a review of the National Inventory Reports (NIRs) of other countries.

The sections below outline the emission sources from feedstock and NEU of fuels that are included in the UK GHGI, the source data and estimation methods and a summary of the time series for each of the fuel types where there is a stored carbon component in the UK energy balance. The estimates are all presented in CRF Tables 1.Ab and 1.Ad.

Table 3-1 Summary of Emission Sources for UK Fuels Allocated as Non Energy Use in UK Energy Statistics

Fuel	IPCC	Source Category
Liquid Fossil		
Naphtha, LPG and Ethane[19]	1A1a	Scrap tyre combustion in power stations (1994 to 2000 only). Fossil carbon in MSW combustion in energy from waste plant. *Emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and plastics.*
	1A1b	Other petroleum gas use in refineries (2004 to 2011 only). *Re-allocated from non-energy use as EU ETS and trade association data indicates that DUKES data on OPG combustion are an under-report.*
	1A2f	Carbon in energy recovery from waste solvent, in cement kilns. Industrial combustion of waste solvents. Scrap tyre combustion in cement kilns. *Emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and solvents.* Other petroleum gas use in petrochemical facility combustion. *Re-allocated from non-energy use as EU ETS and operator data indicates that DUKES data on OPG combustion are an under-report*
	2B5	Energy recovery from process gases in the chemical industry. Release of carbon from chemical products such as soaps, detergents. Release of carbon from pesticides. *Emissions of carbon from chemical feedstock via breakdown of products..*
	6C	Fossil carbon in chemical waste incineration. Fossil carbon in MSW incineration. Fossil carbon in clinical waste incineration. *Emissions of carbon from chemical feedstock via combustion of products such as synthetic rubbers and plastics.*
Lubricants	1A1a	Waste oil combustion in power stations.
	1A2f	Waste oil combustion in unclassified industry (including road-stone coating plant) Waste oil combustion in cement kilns. Lubricant combustion in industrial engines.
	1A3a	Lubricant combustion in aircraft engines.
	1A3b	Lubricant combustion in road vehicle engines.
	1A3d	Lubricant combustion in marine shipping engines.
	1A4c	Lubricant combustion in agricultural engines.
	6C	Waste oil use in MSW incineration.
Bitumen	n/a	*No known UK applications that lead to GHG emissions.*
Gas/Diesel Oil	n/a	*No known UK applications that lead to GHG emissions.*
Petroleum coke	n/a	*There are a range of source sectors reported in DUKES as including some level of petroleum coke as fuel use across some or all years,*

[19] Naphtha, LPG and ethane are aggregated and analysed together to derive estimated stored and emitted carbon fractions. It is assumed that the NEU of these fuels accounts for the primary carbon inputs to chemical and petrochemical production that are subsequently emitted through combustion, use or degradation of chemical products / off-gases.

Fuel	IPCC	Source Category
		whereas other evidence indicates much higher petroleum coke use in those source categories. See text below for details of re-allocations from non-energy use data in the energy balance to address these under-reports. We note that the data presentation for petroleum coke in the CRF table 1Ad is inconsistent with other fuels and this will be revised in future submissions. This does not affect the UK GHGI totals, however.
Other Oil	2B5	Carbon released from use of petroleum waxes.
Solid Fossil		
Coking coal (coal oils and tars)	n/a	*Unknown quantities of coal tar pitch are used in the manufacture of anodes for industrial processes. The emissions from the use of these anodes are allocated against petroleum coke (also used in anode production). This is a small mis-allocation of emissions between the two fuels due to lack of detailed data, but does not affect the accuracy of UK inventory emissions.*
Gaseous Fossil		
Natural Gas	2B1	Ammonia production leading to either direct release of CO_2 or associated chemical production (of methanol) with subsequent release of carbon originating in the natural gas feedstock.

Naphtha, Ethane, Propane and Butane (LPG)
Ethane, LPG (given separately as propane & butane in the energy statistics) and naphtha are all consumed in very significant quantities for non-energy uses, primarily as feedstock in chemical manufacturing. In the UK, several major petrochemical production facilities are supplied with Natural Gas Liquid (NGL) feedstock directly from upstream production pipelines, and then utilise NGL fractions such as ethane, propane and butane in their manufacturing processes.

All of the consumption given in DUKES is assumed to be initially stored in chemical products, although some emissions of carbon do then occur during subsequent use or destruction of some of those products e.g. when some waste chemical products are incinerated or used as fuels. Although emissions from incineration and combustion of wastes are estimated, we cannot relate the carbon in these wastes back to individual feedstock, so it is not possible to generate reliable UK estimates of the proportion of carbon that is ultimately emitted from each individual fuel. Some butane is used as a propellant in aerosols and is emitted as VOC. The UK inventory contains estimates of these VOC emissions, combined with emissions of solvents used in aerosols.

The method aggregates the carbon content of the non-energy use allocations for ethane, LPG and naphtha, and then subtracts the carbon emission estimates from inventory sources (listed in the table above) to derive an estimate of remaining UK stored carbon across this group of feedstock chemicals; it is impossible to assess the stored carbon fractions of the individual fuels, and hence the annual storage fractions presented in the CRF are identical for ethane, LPG and naphtha.

In the 2013 submission, the inventory agency has generated new time series estimates of ethylene production and the use of NGL-derived off-gases as a fuel in those production processes, using plant capacity data for the UK's 5 sites and reported CO_2 emissions, EU ETS fuel use data and operator information. This is a new re-allocation of fuel that within DUKES is allocated to non-energy use, but within the inventory is allocated to combustion sources reported in 1A2f.

Emissions can also occur from breakdown or combustion of products from the chemical industry that contain "stored carbon" from feedstock that in DUKES is allocated to non-energy use. Sources of emissions include burning of waste products and final products (e.g. flaring and use of wastes as fuels, or burning of candles, firelighters and other products etc.) or degradation of products after disposal resulting in CO_2 emissions (including breakdown of consumer products such as detergents etc.).

In the assessment of storage factors for ethane, naphtha and LPG, emission sources allocated to those fuels are:

- Carbon emitted during energy recovery - chemical industry;
- Carbon in products - soaps, shampoos, detergents etc.; and
- Carbon in products – pesticides.

A full time series of emissions is included in the inventory, and details of the methodology for these sectors are given in Passant, Watterson & Jackson, 2007. Emissions are reported under 2B5.

[Emissions in 2B5 from petroleum waxes are accounted for in the UK inventory under the fuel category "Other Oils" in CRF table 1Ad (see below).]

Emissions from products that contain fossil carbon that are oxidised in incinerators (MSW, chemical, clinical) are included in the GHG inventory and reported under 6C; where the use of such wastes as fuel includes power generation, the emissions are allocated in 1A1a. In the UK there have been short periods where scrap tyres have been used as a power station fuel, and these emissions are accounted against ethane, naphtha and LPG also. Tyres contain a mixture of natural and synthetic rubbers, however, and the emission estimates for combustion of scrap tyres in the UK inventory take account that only some of the carbon emitted is from fossil fuels.

Lubricants

Lubricants are listed separately in the UK energy statistics and are used in vehicles and in machinery. The inventory includes estimates of emissions of carbon due to oxidation of lubricants during use, and also includes estimates of emissions from the combustion of waste lubricants and other oils used as fuel.

UK GHG inventory estimates of the quantities of lubricants burnt are based on data from Recycling Advisory Unit, 1999; BLF/UKPIA/CORA, 1994; Oakdene Hollins Ltd, 2001 & ERM, 2008, as well as recent research to access information regarding the UK market for waste oils and the impact of European Directives to consolidate industrial emission regulations such as the Waste Incineration Directive (Oil Recycling Association, 2010). Estimates of waste oil combustion are derived for the following source categories:

- 1A1a Power stations
- 1A2f Cement kilns
- 1A2f Other (unclassified) industry
- 6C MSW Incineration

The estimated emissions for other industry assume that waste oils are used by two sectors: road-stone coating plant and garages. Other sectors may use waste oils as a fuel or as a reductant, but research to date provides no compelling evidence that there is a gap in the UK inventory for waste oil use by industrial operators.

The emission trends from power station use of waste lubricants reflect the fact that the Waste Incineration Directive (WID) had a profound impact on the market for waste oil, used as a fuel. It is assumed that no waste oil was burnt in power stations for the years 2006-2008. In 2009 a Quality Protocol[20] was introduced that allowed compliant fuel produced from waste oils to be burned as non-waste.

Carbon dioxide emissions from the oxidation of lubricants within vehicle engines are based on UK research to analyse the elemental composition of waste oil (Passant, 2004).

UK research into the fate (including combustion) of lubricating oils within engines has been conducted periodically, with one study providing an estimate of 16% of all lubricants burned in engines in 1989, and a 2005 study estimating the total to be 13% of all lubricant supply in 2004. The estimated percentage of total lubricant demand oxidised in engines for 1990-2003 is interpolated between the 1989 and 2004 values, and the 2004 estimate is extrapolated forwards across all years to 2011. The DUKES publication provides annual estimates of total lubricant demand, against which the annual percentage burned estimates are applied to derive the total UK lubricant combustion total; the total lubricant losses are allocated across the different source categories (including road, rail, marine, off-road and air transport) using the more detailed source-specific analysis within the 2005 study.

The 2005 study (Norris and Stewart, 2005) also led to a revision to the assumptions regarding re-use or combustion of lubricating oils within industrial machinery.

Bitumen

In the UK, bitumen is used only for applications where the carbon is stored. By far the most important of these is believed to be the use of bitumen in road dressings. The inventory does assume that a very small proportion of the carbon in the bitumen itself is emitted as VOC during road-stone coating but does not include any estimates of direct carbon emissions from uses of bitumen.

Coal Oils and Tars

Coal-tars and benzoles are by-products of coke ovens and consultation with coke oven operators indicates that all of the coal-tars and benzoles produced are sold for use in the manufacture of chemicals and other products and that the carbon is assumed to be stored. In the UK inventory, we assume the IPCC default assumption that 6% of coking coal is transformed into coal oils and tars, and then the carbon stored is recorded in the coking coal line of table 1A(b) and under “Coal oils and tars (from coking coal)” in table 1A(d).

Coal-tar pitch is used in the manufacture of electrodes, together with petroleum coke and the carbon ultimately emitted, but details of input materials are scarce; emissions of carbon from these sources are included in the inventory attributed to petroleum coke. This may introduce a small mis-allocation of emissions between petroleum coke and coal oils and tars.

Natural Gas

Natural gas is used as a chemical feedstock for the manufacture of ammonia and methanol. Emissions either occur directly as a result of the manufacturing process or (in the case of methanol) are assumed to ultimately occur upon degradation of the chemical products. The emissions are reported under 2B1.

[20] http://www.environment-agency.gov.uk/business/topics/waste/116133.aspx

Most of the emissions from feedstock use of natural gas in ammonia production are at source, i.e. waste gases containing carbon are emitted directly from the ammonia plant. However, in keeping with IPCC guidance for the sector, the emissions also include carbon sequestered in methanol, which in the UK is produced as a by-product using the ammonia process CO_2 emissions. The methanol produced using carbon derived from natural gas feedstock will be used for various applications, including in consumer products such as antifreeze and screen-wash, as well as a raw material for petrochemical manufacture.

Gas / Diesel Oil

The UK energy balance for gas oil indicates a relatively high allocation of gas oil use in non-energy uses (125kt in 2011, which is around 2.5% of total UK supply) and these data are reflected in the UK GHG inventory, and the carbon stored is reported in CRF table 1.A(d). There is no detailed information within the energy balance reporting to indicate the applications for non-energy use of gas oil, but the DUKES data are based on fuel supplier estimates of fate of their products. The inventory agency has no other evidence to indicate the fate of that gas oil, and it is assumed that the gas oil may be used within chemical or petrochemical manufacturing processes and hence is entirely stored carbon. One possible use of gas oil is in the manufacture of explosives such as ANFO (usually derived from ammonium nitrate and fuel oil, but gas oil may also be used) which are used in mining and quarrying. This is a source that requires further research to investigate, however.

Other Oil (industrial spirit, white spirit, petroleum wax, miscellaneous products)

White Spirit and Special Boiling Point (SBP) spirits are used exclusively for non-energy applications, and are listed in CRF Table 1.A(d) within the category 'other oil'. They are used as solvents; SBP spirits are used for industrial applications where quick drying times are needed (e.g. adhesives and other coatings) while white spirit is used as a solvent for decorative paint, as a cleaning solvent and for other applications. Estimates of VOC emissions are included in the UK inventory but no estimates are made of direct emissions of carbon from these products, as they are regarded as "not occurring".

The only emissions from this group of petroleum feedstock that are included in the UK GHG inventory are the releases of carbon from petroleum waxes which are reported under 2B5. These are accounted for in the UK inventory under the fuel category "Other Oils" in CRF Table 1.Ad.

Petroleum Coke

The evidence from industrial reporting of fuel use and from periodic surveys of fuel producers that use petroleum coke to produce domestic fuels (including smokeless fuels) indicates that the allocation of petroleum coke to combustion activities in the UK energy balance is an under-estimate across all years. Therefore, the inventory agency generates revised estimates for all combustion activities and effectively re-allocates some of the petroleum coke reported in DUKES as non-energy use to emission sources in the UK inventory.

The data handling and reporting for petroleum coke is inconsistent with that for other feedstock fuels, and this is a priority for revision in the next UK inventory submission. In the CRF tables, the allocation of non-energy use for petroleum coke is correct, but it is not consistent with the data presented in DUKES, and the 100% storage fraction does not reflect the re-allocations that are made to account for the known uses of petroleum coke in combustion processes, that are cited as "NEU" in DUKES.

Petroleum coke listed as used in non-energy applications in DUKES includes some used in combustion and process applications that ultimately result in emissions that are reported within the inventory, for the following source categories:

- 1A1a: Power station use of petroleum coke, primarily within blends with coal at a small number of UK facilities;
- 1A1b: Refinery emissions from regeneration of catalysts;
- 1A2f: Cement industry use of petroleum coke as a fuel;
- 1A2f: Other industry use of petroleum coke as a fuel;
- 1A4b: Petroleum coke use within domestic fuels;
- 2C1: Carbon emissions from anode use in Electric Arc Furnaces;
- 2C3: Carbon emissions from anode use in primary aluminium production.

The UK inventory agency makes independent estimates of the consumption of petroleum coke in these sectors, based on data provided by industry and in some cases reported via the EU ETS (since 2005). Some of this consumption is used for applications where carbon emissions do ultimately occur, such as manufacture of electrodes used in aluminium and steel production.

DUKES contains only limited information on the use of petroleum coke as a fuel, although it does give data on UK production, imports and exports of petroleum coke, allowing total UK consumption to be derived. However, these data will cover two distinct types of petroleum coke – fuel grade (green) coke and anode grade coke, with the former being used as a fuel, and the latter being used in various processes. As a first order estimate of UK consumption of petroleum coke as a fuel, it could be assumed that all production and exports are anode grade coke (the UK does not produce fuel grade coke) and that all imports are fuel grade coke.

The inventory contains estimates of petroleum coke consumption by various sectors. It is burnt in **cement kilns** and in a handful of **power stations**. A few other **large industrial sites** have also used the fuel. Good estimates of the consumption of petroleum coke by these large sites are available from the operators themselves, from trade associations and from EU ETS data.

Fuel grade petroleum coke is also used as a **domestic fuel** (both smokeless and non-smokeless types). The inventory agency uses data supplied by the UK fuel supply industry to estimate petroleum coke consumption for domestic fuels over the period 1990 – 2011; these estimates are broadly consistent with fuel use data published in DUKES for a few years in the late 1990s.

Carbon deposits build up with time on catalysts used in **refinery** processes such as catalytic cracking. These deposits need to be burnt off to regenerate the surface area of the catalyst and ensure continued effectiveness of the catalyst; emissions from this process are reported within EU ETS since 2005, with the time series estimates provided by the trade association (UKPIA, 2012) and the catalyst regeneration is treated in the inventory as use of a fuel (since heat from the process is used) and are reported under 1A1b.

Estimates of carbon released from anodes during **metal processes** are estimated based on operator data and reported in 2C1 and 2C3. Petroleum coke content of these anodes is estimated based on operator data and literature sources such as BREF notes.

The remaining 'non-energy' consumption, following subtraction of these estimates from the DUKES UK supply total, is then assumed to be the true consumption of petroleum coke for non-energy uses, and these data are reported within the CRF table 1.Ad with a 100% storage fraction cited, which, as outlined above, is somewhat misleading and will be revised in future submissions.

All of these revised allocations still leaves significant residual levels of petroleum coke allocated to "non-energy use" for most years in the time series, and we note that it is possible that further uses of petroleum coke as a fuel do exist. The consumption estimates for industrial plant are likely to be highly accurate for those sites and for the sectors involved, but other sectors may also include sites that use petroleum coke. The estimates for domestic use as a fuel are more uncertain, being based on expert judgement, but the uncertainty is not high enough to suspect that this source may account for much / any of the residual non-energy use petroleum coke.

Carbon factors for petroleum coke use are derived from industry-specific data (including EU ETS fuel analysis) in the case of cement kilns (MPA, 2012), power stations and other industrial sites (EA, 2012; SEPA, 2012). The petroleum coke factor for refinery consumption is based on trade association analysis conducted as part of the 2004 Carbon Factors Review (UKPIA, 2004) while the factor for domestic consumption is based on compositional analysis of samples of petroleum coke sold as domestic fuels (Loader et al, 2008).

These factors do show quite a large variation from sector to sector: this is perhaps partly a real reflection of the different requirements of fuels for different sectors (higher quality, higher carbon for some, less so for others), but may also indicate inadequacies in the data for some sectors where good quality EU ETS-based factors are not available. The highest carbon factor is for 'petroleum coke' burnt in sector 1A1b, but this fuel is actually of a different nature from the fuel burnt as petroleum coke in sectors 1A1a, 1A2f and 1A4b. In the case of 1A1b, the fuel is a build-up of carbon on catalysts used in various refinery process units, while in the other three cases, the petroleum coke is a solid by-product of a totally different refinery process (coking) which has different characteristics.

The total emissions and carbon stored from petroleum coke for selected years across the time series are presented below. Note that the data on stored carbon are consistent with those reported as "100% stored" in the CRF:

Table 3-2 Petroleum Coke Carbon Emissions and Carbon Stored across all UK Supply 1990-2011

	Units	1990	1995	2000	2005	2010	2011
Petroleum coke emissions *(Sum of: 1A1a, 1A1b, 1A2f, 1A4b, 2C1, 2C3)*	kt Carbon	224	452	561	657	358	228
Petroleum coke – stored carbon	kt Carbon	363	355	59	178	287	227
Storage fraction across all UK supply of petroleum coke	%	62	44	10	21	44	50

3.2.6.2 CRF Reporting Notes: Feedstock and NEU of Fuels

There are a number of examples where emissions are reported that are derived from the DUKES data on feedstock and non-energy use of fuels, and these emission estimates are summarised in the column "Associated CO2 emissions" with the IPCC source categories where these emissions are allocated included in the "Allocated under" column in Table 1A.d.
In the 2013 submission, the reporting of underlying activity data for activities such as ethylene production and ammonia production have been updated in Table 2(I).A-Gs-1, to match the time series of data that has been used to derive the estimates of emissions from feedstock chemicals and the storage of carbon within chemical products. This has improved the consistency of data reporting within the CRF and improves transparency regarding the emissions and storage of carbon from these (petro)chemical production processes.

3.2.6.3 Carbon Storage Fractions: Import-Export balance for Carbon-containing Materials

The analysis within the UK energy statistics or GHG inventory compilation system cannot accurately account for the variable (over time) import-export balance of carbon-containing materials in the UK economy. For example, where the inventory agency accounts for the carbon emissions from of scrap tyres burned in cement kilns, power stations, incinerators and so on within the inventory estimates or from the degradation of plastics or released from detergents and other chemicals, there is no way of tracing the quantity that is derived from imported tyres/plastics/detergents.

The reported estimate of the fate of the reported NEU of fuels from the UK energy balance is based on an assumed "closed system", whereby we account for all emissions from carbon-containing products and fuel types that are allocated as NEU as if they are derived from the fuel statistics in the UK energy balance. Therefore, the storage factors that are presented in the CRF Table 1.Ad (and the time series of storage factors) may be somewhat misleading, as the source of the carbon emitted from feedstock and NEU of fuels will partly be carbon from imported materials, with UK feedstock carbon also exported and emitted elsewhere.

3.2.7 Capture and Storage of CO_2 from Flue Gases

Currently in the UK, CO_2 emitted from flue gases is not captured and stored.

3.2.8 Country specific issues

Country specific issues have been identified under other headings or as they occur.

3.2.9 Source Category 1A1 – Energy Industries

3.2.9.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1A1a: Power stations	T1	CS
	Misc industrial/commercial combustion (district heating)	T1	CS
	1A1b: Refineries – combustion	T1	CS
	1A1c: Coke production	T2	CS
	Collieries – combustion	T1	CS
	Gas production	T2	CS
	Nuclear fuel production	T1	CS
	Solid smokeless fuel production	T1	CS
	Town gas manufacture	T1	CS
	Oil production	T2	CS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-oil, CO_2		
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-coal, CO_2 Stationary combustion-gas, CO_2 Stationary combustion-oil, CO_2		
Key Categories (Qualitative)	None identified		

Overseas Territories and Crown Dependencies Reporting	Emissions from 1A1a included – no emissions observed in 1A1b or 1A1c. All relevant UK Overseas Territories and Crown Dependencies emissions included within category totals within CRF submission – UK EFs used.
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	1A1a: Improved emission factors for MSW used for energy. 1A1c: Improved accuracy and completeness for the fuel use in the upstream oil and gas sector.

[a]T1: Tier 1, T2: Tier 2, T3: Tier 3, CR: Corinair, CS: Country Specific, D: Default, OTH: Other

This source category includes: electricity generation, and the use of fossil fuels for petroleum refining, production of crude oil, natural gas, coal, coke and solid smokeless fuels.

The main fossil fuels used by the UK electricity supply industry are bituminous coal and natural gas. Approximately 41 Mtonnes of coal were burnt at 17 power stations during 2011, while approximately 9,400 Mtherms of natural gas were consumed at 44 large power stations and 11 small (<50MWth) regional stations (mostly Combined-Cycle Gas Turbines, CCGTs). Heavy fuel oil was the main fuel at 3 large facilities, and gas oil or burning oil was used by 4 large and 8 small power stations, as well as being used as a secondary fuel at 10 nuclear power stations.

Bio-fuels are burnt at an increasing number of power generation sites (see **Table 3-3**) to help electricity generators meet Government targets for renewable energy production. Four established sites use poultry litter as the main fuel, another site burns straw, yet another burns wood, whilst many coal-fired power stations have increased the use of biofuels such as short-rotation coppice to supplement the use of fossil fuels. One former coal-fired power station has been converted to operate as a dedicated biomass power station (from 2012 onwards). Electricity is also generated in a large number of engines running on biogas at landfill sites and sewage treatment works. CO_2 emissions associated with biofuel combustion are estimated and reported as memo items, but not included in national totals. Emissions of other greenhouse gases are estimated and included. This is in accordance with IPCC advice in the treatment of biofuels.

Electricity is also generated at 26 Energy from Waste (EfW) installations in the UK. Formerly referred to as municipal solid waste (MSW) incinerators, all such installations are now required to be fitted with boilers to raise power and heat, and their emissions are therefore reported under CRF source category 1A1 (electricity generation), rather than 6C (Waste Incineration). This has been the case since 1997; prior to that year at least some MSW was burnt in older installations without energy recovery.
Table 3-3 gives estimates of the number of power stations by fuel type over the period covered by the inventory.

Table 3-3 Power stations in the UK by type

Year	Coal	Fuel oil	Gas oil	Gas	Waste	Biomass	Biogas
1990	44	9	25	0	2	0	Unknown[a]
1995	23	8	25	5	4	0	Unknown[a]
2000	22	5	25	35	15	4	267

Year	Coal	Fuel oil	Gas oil	Gas	Waste	Biomass	Biogas
2005	17	5	25	47	20	5	461
2006	17	4	24	49	20	5	491
2007	17	4	22	49	20	6	518
2008	17	4	22	49	20	6	535
2009	17	4	22	51	22	6	545
2010	17	4	22	53	23	6	554
2011	17	3	22	55	26	6	565

[a]Number of power stations for early years is unknown although emissions are reported, biogas consumption is obtained from DUKES.

The UK has 11 oil refineries, 3 of these being small specialist refineries employing simple processes such as distillation to produce solvents or bitumens only. The remaining 8 complex refineries are much larger and produce a far wider range of products including refinery gases, petrochemical feedstocks, transport fuels, gas oil, fuel oils, lubricants, and petroleum coke. The crude oils processed, refining techniques, and product mix will differ from one refinery to another and this will influence the level of emissions from the refinery, for example by dictating how much energy is required to process the crude oil.

Most UK coke is produced at coke ovens associated with integrated steelworks, although one independent coke manufacturer also exists. At the end of 2011, there were four coke ovens at steelworks and one independent coke oven. A further three coke ovens have closed in the last decade, due to closure of associated steelworks or closure of other coke consumers. Solid smokeless fuels (SSF) can be manufactured in various ways but only those processes employing thermal techniques are included in the inventory since these give rise to significant emissions. Currently, there are two sites manufacturing SSF using such processes. **Table 3-4** shows how the numbers of refineries, coke ovens and other fuel processing works vary over the period covered by the inventory.

Table 3-4 Fuel processing sites in the UK by type

Year	Crude oil refineries	Specialist refineries	Coke ovens	Other solid fuel manufacturing
1990	11	4	9	6
1995	11	4	8	5
2000	9	3	8	3
2005	9	3	5	2
2006	9	3	5	2
2007	9	3	5	2
2008	9	3	5	2
2009	8	3	5	2
2010	8	3	5	2
2011	8	3	5	2

Crude oil and natural gas are produced mainly from a large number of offshore installations located in the North Sea, together with a small number of production facilities in the Irish Sea or on land. Coal is extracted from a small number of deep mines, and a somewhat larger number of open-cast sites. In 2011, the UK produced almost 49 million tonnes of crude oil and about 1,900 PJ of natural gas, as well as 18.6 Mt of coal.

Nuclear fuel production is a very minor user of fuel in the UK.

3.2.9.2 Methodological Issues

Table 3-5 gives an overview of the estimation methodologies used for 1A1.

Table 3-5 Summary of Emission Estimation Methods for Source Categories in CRF Category 1A1

Source Category	Method	Activity Data	Emission Factors
Power stations	AD x EF	DECC energy statistics, EU ETS, operators	Carbon: EU ETS data, UK-specific factors (Fossil fuels from Baggott *et al*, 2004, MSW factors based on UK-specific waste composition data) CH_4, N_2O: IPCC, USEPA, UK-specific factors
Miscellaneous industrial/commercial combustion	AD x EF	DECC energy statistics,	Carbon: MSW factors based on UK-specific waste composition data. CH_4, N_2O: IPCC, USEPA, UK-specific factors
Refineries	AD x EF	DECC energy statistics, EU ETS	Carbon: EU ETS data, UK-specific factors (Baggott *et al,* 2004), UK refinery operators' data. CH_4, N_2O: IPCC, USEPA, UK-specific factors
Coke production	UK model, AD x EF	DECC energy statistics, ISSB	Carbon: carbon balance for fuel transformations in coke ovens and steelmaking processes (see CRF category 2C1), UK-specific factors for fuels used for energy (Baggott *et al*, 2004 CH_4, N_2O: IPCC, EMEP/EEA
Collieries – fuel combustion	AD x EF	DECC energy statistics	IPCC, EMEP/EEA, UK-specific factors
Gas production (downstream gas)	AD x EF	DECC energy statistics, EU ETS	IPCC, USEPA, UK-specific factors
Gas separation plant	AD x EF	DECC energy statistics, EU ETS	Carbon: IPCC, UK-specific factors CH_4, N_2O: EEMS
Upstream gas production	AD x EF	DECC energy statistics, EU ETS	EEMS and UK-specific factors
Nuclear fuel production	AD x EF	DECC energy statistics	Default factors (IPCC, UK-specific research)
Upstream oil production	AD x EF	DECC energy statistics, EU ETS	EEMS and UK-specific factors
Solid smokeless fuel production	AD x EF	DECC energy statistics, EU ETS	IPCC, UK-specific factors

The majority of emissions of direct greenhouse gases in the energy sector (1A1) are estimated from fuel consumption statistics using the standard approach detailed in the next section. This method involves the use of emission factors, applied to national activity data, and is applied to estimating emissions for direct greenhouse gases from power stations, refineries, and all of the sources included in 1A1c with the exception of coke production, where a carbon balance approach is used for the emissions related to the fuel transformations carried out in the ovens. Further details of the emission factors and activity data used for estimating emissions from 1A1 are given in the following sections.

Emissions data are usually available for individual sites from databases such as the Environment Agency's Pollution Inventory (PI), covering English and Welsh sites, and similar

databases covering sites in Scotland and Northern Ireland. Hence the emissions of indirect gases for a particular sector can be calculated as the sum of the emissions from these point sources. That is:

$$\text{Emission} = \Sigma \text{ Point Source Emissions}$$

However it is still necessary to make an estimate of the fuel consumption associated with these point sources, so that the emissions from non-point sources can be estimated from fuel consumption data without double counting. In general the point source approach is only applied to emissions of indirect greenhouse gases for sectors that consist solely or mainly of large sites (e.g. power stations, coke ovens, refineries). Indirect greenhouse gas emissions from a few energy sector sources consisting of smaller sites are estimated using emission factors (see **Table 3-7** for details of methods for indirect gases).

Emission factors for some secondary fuels such as coke, solid smokeless fuel, and coke oven gas are derived as part of a carbon balance model covering solid fuel manufacture and steelmaking.

3.2.9.2.1 Basic Combustion Module

For all source categories in CRF sector 1A1, emissions result from the combustion of fuel. The activity statistics used to calculate the emission are fuel consumption statistics taken, mainly from DUKES (DECC, 2012), with supplementary data from other UK data sources such as EU ETS reporting and process operators' data. A file of the fuel combustion data used in the inventory is provided on a CD ROM attached to this report. Emissions are calculated according to the following equation:

$$E(p,s,f) = A(s,f) \times e(p,s,f)$$

where

$E(p,s,f)$ = Emission of pollutant *p* from source s from fuel *f* (kg);
$A(s,f)$ = Consumption of fuel *f* by source *s* (kg or kJ); and
$e(p,s,f)$ = Emission factor of pollutant *p* from source s from fuel *f* (kg/kg or kg/kJ).

The pollutants estimated in this way are as follows:

- Carbon dioxide as carbon;
- Methane;
- Nitrous oxide;
- NO_x as nitrogen dioxide (some source/fuel combinations only);
- NMVOC;
- Carbon monoxide (some source/fuel combinations only); and
- Sulphur dioxide (some source/fuel combinations only).

The fuels covered are listed in **Annex 3, Section 3.1**, though not all fuels occur in all sources.

3.2.9.2.2 Emission factors used

Table A 3.2.2 to **Table A 3.2.5** in Annex 3 list the emission factors used in this module, and a summary of the factors has already been given in **Table 3-5**. Emission factors are expressed in terms of kg pollutant/tonne for solid and liquid fuels, and g/TJ gross for gases.

This differs from the IPCC approach, which expresses emission factors as tonnes pollutant/TJ based on the *net calorific value* of the fuel. For gases the NAEI factors are based on the *gross calorific value* of the fuel. This approach is used because the gas consumption data in DECC (2012) are reported in terms of energy content on a gross basis. The tables are grouped into solid, liquid, gas and biomass/other based on the IPCC definitions of the fuels.

Factors are taken from the following data sources:

- UK-specific fuel-specific or sector-specific data (e.g. Baggott *et al*, 2004)
- UK-specific, site-specific data sets (EU ETS, EEMS, operators' data)
- IPCC guidance
- Other international guidance, emission factor compilations and literature sources (e.g. EMEP-CORINAIR, US EPA)

UK sector-specific and/or fuel-specific emission factors for carbon were the subject of an in-depth review during 2004, with revised emission factors for the period 1990-2003 generated after extensive consultation with fuel suppliers and users. The results were published in Baggott *et al*, 2004, and the emission factors in this report still form much of the basis for the emission estimates for 1990-2003. The emission factors are Tier 2, but rely upon significant quantities of site-specific data (e.g. for coal-fired power stations) or other high quality data such as gas composition data provided by the gas suppliers. Where carbon factors given in the review need to be updated annually, this is done either by collecting new data from industry so that the same methodology can be used to produce updated factors, or by scaling from the carbon factors for 2003, using the gross calorific values presented in the latest version of the Digest of UK Energy Statistics (DECC, 2012). The carbon content of a fuel is closely correlated with the calorific value and so using calorific value as a proxy provides a good estimate of the changing carbon contents.

The factors in Baggott *et al*, 2004 are supplemented by emission factors based on high quality site-specific emissions data available from the EU ETS data set, covering 2005-2011, and from the EEMS dataset (1997-2011). The use of EU ETS data is described in detail in **Annex 9.** EU ETS data are used for the most significant sources of carbon in 1A1. CO_2 emission factors for coal, fuel oil, petroleum coke, natural gas and sour gas use in power stations and fuel oil, petroleum coke, and refinery fuel gas (OPG) use in refineries are based on data reported to the EU Emissions Trading System (EU ETS) for the years 2005-2011. These data are of high quality, and available for all significant UK power plants and refineries - some very small power stations, e.g. on remote islands, will not report to EU ETS but their fuel use will be negligible. Due to the use of site-specific data, CO_2 emission factors for these source categories are Tier 3. EU ETS data are not available before 2005, therefore emission factors for earlier years must be calculated in a different way. The factors in Baggott *et al*, 2004 cover the period 1990-2003 and are considered the best available data for that period and so for many sources within 1A1, emission estimates for 1990-2003 are based on factors from Baggott *et al*, 2004, and emission estimates for 2005 onwards are based on factors derived from EU ETS data. Extrapolation back from the EU ETS data across the entire time series is not considered sufficiently reliable to replace the factors taken from the 2004 review. Emission factors for 2004 are predominantly assumed to be the same as in 2003.

Site-specific data are also available for offshore oil and gas exploration and production facilities via the EEMS reporting system and these are used for the estimates for several source categories within 1A1c. Unlike EU ETS, the EEMS dataset covers multiple pollutants

and can be used to provide emission estimates for both direct and indirect greenhouse gases. EEMS data are available from 1997 onwards, although the quality and completeness of the data may differ across the time-series.

Where UK-specific factors and data are not available, international guidance and other literature sources have been used. IPCC guidance documents have provided many of the emission factors for methane and nitrous oxide, with other factors obtained from the EMEP-CORINAIR Emission Inventory Guidebook (EMEP/EEA, 2009) or the US EPA's AP-42 publication (USEPA, 2012). Two reports by the Coal Research Establishment on emissions from coal-fired appliances (Brain *et al*, 1994 and Fynes & Sage, 1994) are also used.

As well as the annual data sets from EU ETS and EEMS, the following updates are routinely collected for use in deriving emission factors for the inventory:

1. The UK Petroleum Institute Association (UKPIA) advise whether the carbon emission factors supplied by them for the 2004 review continue to be valid. The UKPIA factors were based on fuel analyses and covered the following fuels:

    - Petrol;
    - Burning oil;
    - ATF;
    - Aviation spirit;
    - Diesel;
    - Fuel oil;
    - Gas oil;
    - Petroleum coke;
    - Naphtha;
    - OPG;
    - Propane; and
    - Butane.

2. Natural gas carbon factors, based on gas composition data, are provided annually by the UK gas distribution network operators and are derived from extensive measurements of the natural gas fuel delivered to UK consumers.

An updated and improved CO_2 emission factor for MSW has been derived for this version of the inventory. Whereas previously a fixed emission factor, taken from a literature source, was used across the time-series, now waste composition data as used in the UK inventory landfill model has been used to calculate year-specific, UK-specific emission factors. The approach relies on the assumption that the composition of waste in those areas of the UK which burn waste for energy is the same as the composition of waste in those areas that landfill it. The carbon intensity of different material types e.g. plastic film, dense plastics, textiles etc. within the waste is taken from a UK study (ERM, 2006) and the carbon content of each material type is assumed to remain constant across the time-series. The carbon contents calculated by the study are summarised in **Table 3-6** and emission factors are based on the fossil carbon content given in the table, assuming all carbon is oxidised.

Table 3-6 Biogenic and fossil carbon content of residual waste (time series)

Year	Biogenic carbon (kgC/T residual waste)	Fossil carbon (kgC/T residual waste)	Total carbon (kgC/T residual waste)	Proportion of carbon content which is fossil origin
1990	174	83	257	32.4%
1991	175	85	260	32.8%
1992	175	87	263	33.3%
1993	176	89	265	33.7%
1994	177	91	268	34.1%
1995	166	72	238	30.3%
1996	164	69	233	29.6%
1997	161	65	227	28.9%
1998	159	62	221	28.1%
1999	157	59	216	27.3%
2000	155	56	210	26.5%
2001	155	60	215	28.1%
2002	155	66	220	29.8%
2003	155	71	226	31.6%
2004	154	77	232	33.4%
2005	154	84	238	35.3%
2006	152	95	247	38.4%
2007	150	98	248	39.6%
2008	148	101	248	40.5%
2009	146	98	243	40.1%
2010	143	94	238	39.6%
Values used previously	225	75	300	25.0%

A revised emission factor has been used for OPG burnt at oil and gas terminals following a review of the data from upstream oil and gas operators and consultation with the DECC energy statistics team to clarify the scope of DUKES data for the oil and gas sector. In previous submissions, the OPG factor for gases burned at gas separation plant at oil refineries was assumed to be similar in composition to refinery fuel gas. However, through consultation with DECC DUKES (Personal communication: Clive Evans, 2012) the reported gas use at oil terminals is assumed to be NGL-derived gases, predominantly ethane in composition and therefore the emission factor has been revised across the time series to use the IPCC default for ethane, to improve accuracy of the estimates; this new factor is approximately 20% higher than the factor previously used.

EEMS emissions data are used for natural gas burnt by the upstream oil and gas industry but the carbon emission factors implied by use of these emissions data have changed, following revisions to the activity data used (described in the next section). The implied emission factors used previously had been identified in reviews as outliers, and the revised values are more characteristic of natural gas. A further revision to the time series concerns the use of EEMS data back to 1997 only, rather than 1996. Following the changes to activity data, the 1996 emissions data and implied emission factor looked to be unreliable and so have been discarded, with emissions for 1990-1996 all being calculated using the 1997 implied emission factor.

The implied emission factors (IEFs) presented in the UK CRF are generally aggregates of data at a more detailed level that is available in the UK inventory. This means the IEFs can vary across the time-series as both the activity data and the emission factors change for each set of detailed emission estimates. Updating carbon factors for the detailed sectors each year can cause large inter-annual changes in IEFs reported in the CFR. One approach to avoid this, which has been suggested by an UNFCCC Expert Review Team, is to use regression analysis and derive the CEFs from the best fit line. We have considered this approach and discussed with UK DECC. For the moment, the UK continues to update CEFs on an annual basis because it considers that this approach provides the most accurate estimates of carbon emissions in a given year.

In general, we would not expect the UK-specific emission factors derived for the UK inventory to be significantly different from factors derived for other Member States of the European Union. However, there are some UK circumstances which may result in some differences with emission factors elsewhere. In particular, for sector 1A1a, the carbon factors for gas are higher in some years than might be expected because sour gas has been used in the UK ESI sector from 1992 onwards, and sour gas has a higher carbon factor than natural gas. The large increase in the CO_2 IEF between 1991 and 1992 is explained by the start-up of Peterhead power station in Scotland. This station burned large volumes of sour gas at that time, but after the mid-1990s, the quantities rapidly decreased again and the impact of sour gas on the UK IEF for gas should be small for the later part of the time-series.

Table 3-7 gives some basic information on the methods used to calculate emission estimates for indirect greenhouse gases.

Table 3-7 Methods used for deriving emission estimates for indirect greenhouse gases for CRF Source Category 1A1

Pollutant	CO	NOx	SO_2	NMVOC
Power Stations	R	R	R	R
Refineries	F/R	F/R	F/R	F
Coke ovens	F/R	F/R	R	F/R
SSF Manufacture	R	R	F	F
Collieries	F	F	F	F
Nuclear Fuels	F	F	F	F
Gas Production (distribution network)	F	F	F	F

Key:

F national emission estimates derived from emission factors and fuel consumption statistics (mostly DUKES)

R national emission estimates derived from site-specific emission estimates reported by process operators to regulators

F/R national emission estimates derived from either emission factors and fuel consumption statistics or site-specific emission estimates reported by process operators to regulators, depending upon fuel type.

There are no emissions observed in 1A1b or 1A1c for any overseas territories or crown dependencies. Fuel consumption data from 1A1a was provided by each territory. These data do not necessarily cover the entire time series so interpolation and extrapolation are applied to produce a complete time series. UK GHGI emission factors were applied to these activity data for all sources.

3.2.9.2.3 Activity data used

Activity data are predominantly taken from DECC (2012), but some alterations are made to the basic fuel consumption statistics available from this dataset (see **Annex 3.3**), to ensure consistency between the GHGI and fuel use data reported by certain process operators. Overall fuel consumption in 1A1 in the GHGI is, however, still consistent with DUKES, with the exception of certain petroleum-based fuels. For petroleum coke, fuel oil, gas oil and burning oil, statistics that are available through sources such as EU ETS returns indicate higher fuel use in the UK energy sector than is implied by the energy statistics. The data sources for petroleum coke use are described in each of the sectors where this fuel is used. For oils consumed in power stations. DUKES reports less fuel burnt by power producers than is reported by operators either directly to the inventory agency or via the EU Emissions Trading System (EU ETS). Therefore fuel oil, gas oil, and burning oil are reallocated from industry to power stations to ensure consistency with operator data, while maintaining consistency with the overall fuel consumption data in DUKES.

For OPG, analysis of EU ETS data from refineries for the 2012 submission identified a discrepancy in activity data between EU ETS and DUKES. Based on data from EU ETS and the refinery trade association, UKPIA, a systematic under-report was identified in the UK energy balance data for the refinery sector from 2004 onwards. The estimates for 2004 in the UK GHGI are therefore based on UKPIA data, whilst the data for 2005 onwards are based on EU ETS data. Prior to 2004 the UK GHGI emission estimates based on DUKES energy data are closely consistent with UKPIA sector estimates, and are therefore retained.

Activity data for the combustion of petroleum coke also require amendment. Significant differences have been found between petroleum coke consumption derived from EU ETS data compared with the petroleum coke use given in DUKES. Therefore the emission estimates are based on the EU ETS total, and the activity data for this fuel is then calculated for 2005 onwards based on the reported EUETS emission and an emission factor provided by the refinery sector (UKPIA, 2012).

Further adjustments are made to activity data for source categories in 1A1c, with revisions to OPG and natural gas activity data for the upstream oil and gas inventory, in consultation with the DECC DUKES team. Mismatches was identified between EEMS emissions and DECC DUKES data from PPRS, with gaps in DUKES:

- from 2003 onwards for LPG/OPG use in oil terminals, and
- prior to 2001 for gas use in onshore terminals.

These gaps have been filled using EEMS and EU ETS activity data for these facilities.

EU ETS data also indicates that more natural gas is used by the downstream gas industry in gas compressor stations than is available in DUKES for the sector. So, for the year 2005 onwards, an adjustment is made to the gas consumption data in the inventory with gas transferred from 1A2 to 1A1c to ensure that the inventory figure matches the figure given in EU ETS.

3.2.9.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type. Uncertainty estimates for the activity data for fuel combustion sources are based on the statistical difference between supply and demand in DUKES, except for fuels where the total fuel use allocated in the inventory deviates from the national

total in DUKES (OPG, petroleum coke). For these fuels, expert judgement has been applied to estimates for each of the categories where the fuels are used.

Most of the core activity data for this source category is derived from the DECC publication, DUKES. **Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A.

Combustion emissions from the NAEI category 'Gas separation plant' are reported under category 1A1c. Background energy data for the calculation of these emissions are taken from the most up to date version of DUKES. In the DUKES published in 2002, DECC (formally DTI) stopped collecting the activity data about oil and gas extraction previously used to estimate these emissions. EU ETS data have been used for the years 2008 to 2011, and EEMS activity data trends have been used to derive estimates for 2003 to 2007 for this activity. For more information about how EU ETS data are used, refer to **Annex 11**.

Emissions from petroleum coke consumption in refineries are based on DUKES data and an emission factor (UKPIA, 2012) from 1990 to 2004, and EU ETS emissions data from 2005 onwards. As explained in **Section 3.2.6.2**, the EU ETS emissions data are not consistent with the data presented in DUKES for this sector. The time series of fuel consumption presented in DUKES has been compared with the estimates derived from the EU ETS data and the UKPIA emission factor. The differences are mostly small, and represent an underestimate in DUKES from 2005 to 2008 and in 2011, and an over estimate in 2009 and 2010. This does not imply a systematic under or overestimate that could be corrected for by applying an average scaling factor to data from earlier years, therefore the DUKES data has been retained from 1990 to 2004.

For emission factors, the main issue regarding consistency is the use of factors taken from Bagott *et al*, 2004 for the years 1990-2003 and then the use of EU ETS-based emission factors from 2005 onwards for certain sectors, with interpolated values used for 2004. This is a change of methodology within the time series, but both sets of data represent the best available data for the years in question, and the values from both sources are similar, suggesting that the two methods give broadly consistent results. The two sets of data have therefore been combined without any adjustments to either set of factors.

Table 3-8 Time series consistency of emission factors (EFs) of direct GHGs used in source category 1A1

GHGs	Source category	Fuel types	Comments on time series consistency
Carbon	1A1	All fuels	• EFs vary somewhat across the time series based on comprehensive carbon factor review in 2004 and EU ETS data for some fuels from 2005 onwards. • Key sources of carbon EF data include: UKPIA, Association of Electricity Producers, Powertech, Transco, EU ETS.
CH_4, N_2O	1A1	All fuels	• Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments..

3.2.9.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

The core publication for Activity Data is the annual DECC publication – *DUKES* – which is produced in accordance with QA/QC requirements stipulated within the UK Government's - *National Statistics Code of Practice*- and as such is subject to regular QA audits and reviews.

Where emissions data are provided by plant operators to the UK environmental regulatory agencies (EA, SEPA, NIEA) and reported via their respective inventories of pollutant releases (and then used in the UK's GHG emission inventory) the data is subject to audit and review within established QA systems. Within England & Wales, the operator emission estimates are initially checked & verified locally by their main regulatory contact (Site Inspector), and then passed to a central Pollution Inventory team where further checks are conducted prior to publication. Specific checking procedures include: benchmarking across sectors, time-series consistency checks, checks on estimation methodologies and the use and applicability of emission factors used within calculations. Similar systems are being developed by SEPA and NIEA, with some routine checking procedures already in place. SEPA conducted a review of data quality during 2011 which has led to some updates to reported emissions data from facilities in Scotland within the Scottish Pollutant Release Inventory dataset.

3.2.9.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3-9** and emission factors in **Table 3-10** below. For information on the magnitude of recalculations to Source Category 1A1, see **Section 10**.

For the OTs and CDs, there have been recalculations to these emission estimates since the previous submission. The Cayman Islands saw the biggest change: an increase on average of 10kt CO_2 (19%) across the whole time series. This was due to a correction in the conversion factors used. There was also a 41% decrease in the 2008 CO_2 estimate from Guernsey due to a revision to the fuel use data provided by Guernsey. It was also stated by the territory that heavy fuel oil is almost all used for electricity generation. However, these recalculations caused only a very small change to UK totals.

Table 3-9 1A1 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
1A1a	Power stations	Landfill gas	18	656	18	653	Mth fuel consumed	DUKES activity data revised for 2010
		Sewage gas	41.1	91.4	41.1	90.8	Mth fuel consumed	DUKES activity data revised for 2007 onwards
		Wood	0.0	1.6	0.0	1.9	Mt fuel consumed	Data supplied for new biomass burning facility from 2008 onwards.
	Public sector combustion	Sewage gas	14	29	14	23	Mth fuel consumed	DUKES activity data revised for 2007 onwards
1A1b	Refineries	Natural gas	9.3	192	9.3	199	Mt fuel consumed	DUKES activity data revised for 2009 onwards
		OPG	1295	1567	1295	1562	Mth fuel consumed	Data updated from 2004 onwards to use UKPIA and EU ETS information to account for fuel consumption missing in DUKES.
		Petroleum coke	1.0	1.4	1.0	1.3	Mt fuel consumed	Revisions to input data for 2005 onwards.
1A1c	Upstream oil production	Natural Gas	887	1507	1013	1274	Mth fuel consumed	Natural gas activity data for the upstream oil and gas inventory has been revised, in consultation with the DECC DUKES team. This has addressed outlier implied emission factors for this source, which have been identified in previous reviews of the UK inventory. A mismatch was identified between EEMS emissions and DECC DUKES data from PPRS, with gaps in DUKES i. from 2003 onwards for LPG/OPG use in oil terminals, and ii. prior to 2001 for gas use in onshore dry gas terminals. These gaps have been filled using EEMS and EU ETS activity for these facilities.
	Upstream gas production	Natural Gas	301	578	344	540	Mth fuel consumed	
	Upstream oil and gas production - combustion at gas separation plant	LPG	11	24	11	7	Mth fuel consumed	
		OPG	152	62	152	135	Mth fuel consumed	

IPCC Category	Source Name	Activity Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
	Upstream oil production	Gas oil	0.35	0.46	0.35	0.49	Mt fuel consumed	DUKES activity data revised for 2010
	Upstream gas production	Gas oil	0.01	0.03	0.01	0.04	Mt fuel consumed	

Table 3-10 1A1 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
1A1a	Power stations	CH4	Waste oils	NA	NA	0.13	0.13	kt / Mt	Emission factors included for the first time. Recommendation from UNFCCC reviewers. IPCC Default for Fuel Oil used.
		N2O	Waste oils	NA	NA	0.026	0.026	kt / Mt	
		CO2	MSW	75	75	83	94	kt C / Mt	Time series of CO2 EFs developed using carbon content of waste.
		CO2	Burning oil	NA	NA	859	859	kt C / Mt	Correction - EFs omitted from previous inventory
		CH4	Burning oil	NA	NA	0.139	0.139	kt / Mt	Correction - EFs omitted from previous inventory
		N2O	Burning oil	NA	NA	0.028	0.028	kt / Mt	Correction - EFs omitted from previous inventory
		CO2	Coal	605	610	605	609	kt C / Mt	Improved treatment of EU ETS data in cases where coal and pet coke are reported as a fuel blend and where previously the carbon content of both components of the fuel blend was assumed to be the same.
		CO2	Coke	813	852	813	854	kt C / Mt	Revisions to DUKES AD. This would affect the carbon balance and, therefore, the CEF for coke, COG & BFG.
		CO2	Petroleum coke	662	605	846	867	kt C / Mt	Improved treatment of EU ETS data in cases where coal and pet coke are reported as a fuel blend and where previously the carbon content of both components of the fuel blend was assumed to be the same.

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
	Miscellaneous industrial/commercial combustion	CO2	MSW	75	75	83	94	kt C / Mt	Time series of CO2 EFs developed using carbon content of waste.
1A1c	Coke production	CO2	Blast furnace gas	7.93	8.58	7.93	8.19	kt C / Mth	Revisions to DUKES AD. This would affect the carbon balance and, therefore, the CEF for coke, COG & BFG.
	Collieries - combustion	CO2	Coal	659.6	675.7	659.6	676.1	kt C / Mt	Update value for calorific value of coal used in this sector, with resulting change in calculated CEF.
	Upstream oil and gas production - combustion at gas separation plant	CH4	LPG	0.004	0.006	0.002	0.002	kt / Mth	Revision to method. Through consultation with DECC, evident that oil terminal reporting of "gas" use and emissions in EEMS includes activity for LPG and OPG. Therefore EF calculation revised. EEMS emissions from "gas" use and aggregate activity data for natural gas, LPG and OPG (in upstream oil only) used to derive IEFs then applied to all fuels for non-CO2 gases. For CO2 IEF, defaults applied for LPG and OPG and the natural gas factor calculated using the EEMS data, accounting for the estimated contribution from LPG and OPg to avoid a double-count.
		N2O	LPG	0.0006	0.0004	0.0005	0.0004	kt / Mth	
		CH4	OPG	0.003	0.006	0.002	0.002	kt / Mth	
		N2O	OPG	0.0006	0.0004	0.0005	0.0004	kt / Mth	
		CO2	OPG	1.49	1.51	1.77	1.77	kt C / Mth	OPG and natural gas activity data and emission factors for the upstream oil and gas inventory have been revised, in consultation with the DECC DUKES team. This has addressed outlier implied emission factors for this source, which have been identified in previous reviews of the UK inventory. It has been noted that OPG used in oil terminals is mainly ethane, therefore the emission factor for OPG in this sector has been revised to reflect this.
	Upstream Oil Production - fuel combustion	CO2	Natural Gas	2.19	1.71	1.67	1.59	kt C / Mth	A better time series of carbon emission factors has been derived for natural gas use, using the higher activity data (outlined above) and EEMS emissions data. In deriving this time series it became clear that the 1996 emission factor (previously used for all years back to 1990) was an outlier, therefore the 1990-1997 emission factors have been based on 1998 data instead, leading to lower emissions in the early part of the time series. The 1998 factors are higher than the factors for most years in the 1998-2011 dataset
		CH4	Natural Gas	0.0035	0.0019	0.002	0.002	kt / Mth	
		N2O	Natural Gas	0.0006	0.0004	0.0005	0.0004	kt / Mth	
	Upstream Gas Production - fuel	CO2	Natural Gas	2.20	1.69	1.68	1.58	kt C / Mth	

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
	combustion	CH4	Natural Gas	0.0035	0.0055	0.0038	0.0043	kt / Mth	(except 2002-3 for oil production and 2002 for gas production), but are regarded as the best available data for estimating the 1990-1997 emissions.
		N2O	Natural Gas	0.0006	0.0004	0.0006	0.0005	kt / Mth	
	Solid smokeless fuel production	CO2	Coke	813	852	813	854	kt C / Mt	Revisions to DUKES AD. This would affect the carbon balance and therefore the CEF for smokeless fuel manufacture.

3.2.9.6 Source Specific Planned Improvements

Emission factors and activity data are kept under review and analysis of EU ETS data will continue.

3.2.10 Source Category 1A2 – Manufacturing Industries and Construction

3.2.10.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1A2a: Iron and Steel (Combustion)	T1	CS
	Iron and Steel (Sinter Plant)	T2	CS
	Iron and Steel (Blast Furnaces)	T2	CS
	1A2b: Non-Ferrous Metals	T1	CS
	1A2c: Chemicals Ammonia	T1	CS
	(Combustion)	T1	CS
	1A2d: Pulp, Paper and Print	T1	CS
	1A2e: Food Processing, Beverages, Tobacco	T1	CS
	1A2f: Other Industry (Combustion)	T1	CS
	Cement (Fuel Combustion)	T1	CS
	Cement (Non-decarbonising)	T2	CS
	Lime Production (Combustion)	T1	CS
	Autogenerators	T1	CS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-oil, CO_2		
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-coal, CO_2 Stationary combustion-gas, CO_2 Stationary combustion-oil, CO_2		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from 1A2f included – no emissions observed in 1A2a-1A2e. All relevant UK Overseas Territories and Crown Dependencies emissions included within category totals within CRF submission.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Improved completeness of emission estimates for industrial use of OPG.		

This source category covers the use of fossil fuels by industrial processes. The structure of the emissions data for this category reflects both the requirements for international reporting of emissions, but also the availability of data at a more detailed level for some industrial sectors.

Iron and steel industry emissions are reported under 1A2a, these emissions being limited to those from the use of fossil fuels in boilers and heat treatment or melting furnaces, the use of

coke in sinter plant and the use of coke oven gas, blast furnace gas and natural gas in the hot stoves used to heat air for blast furnaces.. Other iron and steel industry sources such as emissions from the addition of fuel oil or coke to blast furnaces, or emissions of carbon from basic oxygen furnaces are reported under 2C1. The allocation of activities and emissions between combustion and process source categories for iron and steel and other "contact industries" in the UK GHGI are as consistent as possible with data provided directly from operators (e.g. Tata Steel integrated steelworks data), UK energy statistics and EU ETS (where process emissions are reported separately from combustion emissions).

Sectoral emissions for the non-ferrous metal, chemical, paper, and food and drink industries are then reported under 1A2b to 1A2e. Chemical industry emissions, reported under 1A2c, are separated into those from gas use at ammonia production processes, and other emissions. This is due to the availability of detailed information for ammonia plant.

All remaining industrial combustion plant are reported under 1A2f. Fuels used for cement production and for lime production are reported here but estimated separately since these data are available.

According to IPCC 1996 Revised Guidelines, electricity generation by companies primarily for their own use is autogeneration, and the emissions produced should be reported under the industry concerned. However, most National Energy Statistics (including the UK) report emissions from electricity generation as a separate category. The UK inventory attempts to report as far as possible according to the IPCC methodology

All of the above-mentioned estimates exclude coal and natural gas used for autogeneration, These fuels are given separately in UK energy statistics and are therefore included in the UK inventory as a separate source, reported under 1A2f.

The sectoral estimates reported under 1A2a to 1A2f include fuels reported in the national energy statistics for 'heat generation'. These fuels are assumed to be used by those sites that generate heat to sell to users e.g. many UK paper mills are supplied with steam by a separate combustion plant run by a different operator.

Carbon monoxide emissions reported in the Pollution Inventory from two soda ash manufacturing processes are also reported under 1A2. These emissions are assumed to occur due to the presence of CO in the CO_2 gas that is produced in the associated coke-fired lime kilns (so the CO is, in effect, an emission from the lime kilns).

Emissions from industrial off-road machinery, such as generators and cement mixers, are also reported in this sector.

3.2.10.2 Methodological Issues

Table 3-11 gives a summary of the methodologies used to estimate emissions of direct gases from source categories within 1A2. For all of the source categories, the approach follows the principle of the basic combustion model – the use of emission factors applied to activity data – as described in **Section 3.2.9.2.1**.

Table 3-11 Summary of Emission Estimation Methods for Source Categories in CRF Category 1A1

Source Category	Method	Activity Data	Emission Factors
Blast furnaces	AD x EF	DECC energy statistics	CO_2: UK-specific, including factors from coke and steelmaking carbon balance CH_4, N_2O: IPCC, EMEP/EEA
Sinter plant	AD x EF	DECC energy statistics	CO_2: UK-specific, from coke and steelmaking carbon balance CH_4, N_2O: UK-specific
Iron and steel - combustion plant	AD x EF	DECC energy statistics	CO_2: UK-specific, including factors from coke and steelmaking carbon balance CH_4, N_2O: IPCC, EMEP/EEA, USEPA, UK-specific
Non-ferrous metal (combustion)	AD x EF	DECC energy statistics	CO_2: UK-specific, including factors from coke carbon balance CH_4, N_2O: IPCC, UK-specific
Ammonia production - combustion	AD x EF	DECC energy statistics, operator data.	IPCC and UK-specific
Chemicals (combustion)	AD x EF	DECC energy statistics	CO_2: UK-specific CH_4, N_2O: IPCC, UK-specific
Pulp, paper & print (combustion)	AD x EF	DECC energy statistics	CO_2: UK-specific CH_4, N_2O: IPCC, UK-specific
Food & drink, tobacco (combustion)	AD x EF	DECC energy statistics	CO_2 CO_2: UK-specific CH_4, N_2O: IPCC, UK-specific
Autogenerators	AD x EF	DECC energy statistics	CO_2: UK-specific CH_4, N_2O: IPCC, UK-specific
Cement production - combustion	AD x EF	Mineral Products Association (MPA) data, EU ETS	CO_2: UK-specific, including MPA data CH_4, N_2O: IPCC, UK-specific
Lime production - non decarbonising	AD x EF	EU ETS extrapolated across time-series using PI emissions and BGS production data.	CO_2: UK-specific, including EU ETS data and factors from coke carbon balance CH_4, N_2O: IPCC, UK-specific
Other industrial combustion	AD x EF	DECC energy statistics	CO_2: UK-specific, including EU ETS data and factors from coke carbon balance CH_4, N_2O: IPCC, USEPA, EMEP/EEA, UK-specific
Industrial off-road mobile machinery	AD x EF	Inventory agency estimate of fuel use by different mobile units	CO_2: UK-specific CH_4, N_2O: UK-specific

3.2.10.2.1 Emission factors used

The emission factors used in the inventory are listed in **Annex 3**, **Tables A3.3.1**–**A3.3.4**.

Emission factors for carbon are almost exclusively derived from UK data. Site-specific data, (including both EU ETS data, and data provided by process operators directly or via industrial trade associations) is aggregated up to generate factors for a small number of

sectors. Sector-wide factors are derived in other cases based usually on the methods described in Baggott *et al*, 2004. Emission factors for waste oils are based on the analysis of 8 samples of waste oils collected from UK sites in 2003. Finally, the factors for coke are based on a carbon balance approach as described below.

Emissions of carbon from manufactured solid fuel plants, coke ovens and steelworks are calculated using a model where carbon inputs and outputs are estimated using energy and process statistics and making assumptions about the carbon content of selected inputs and/or outputs and then calculating the quantities of carbon emitted or output at other stages in the process in order to balance the overall inputs and outputs of carbon. The model for manufactured solid fuel plants is straightforward:

$$C_{coal} \rightarrow C_{SSF} + \text{carbon emission}$$

Where C_{coa} and C_{SSF} are the carbon estimated to be contained in the coal (anthracite) input to the fuel manufacturing process, and that in the solid smokeless fuel (SSF) output from the process. The activity data for the calculation is from DECC, 2012. The mass of coal input is always larger than the SSF produced and we also assume a slightly lower carbon content for the SSF compared with the anthracite input, and so there is always an excess of carbon input in coal compared with carbon output in saleable SSF, this excess being treated in the inventory as an emission of carbon by the fuel manufacturing process.

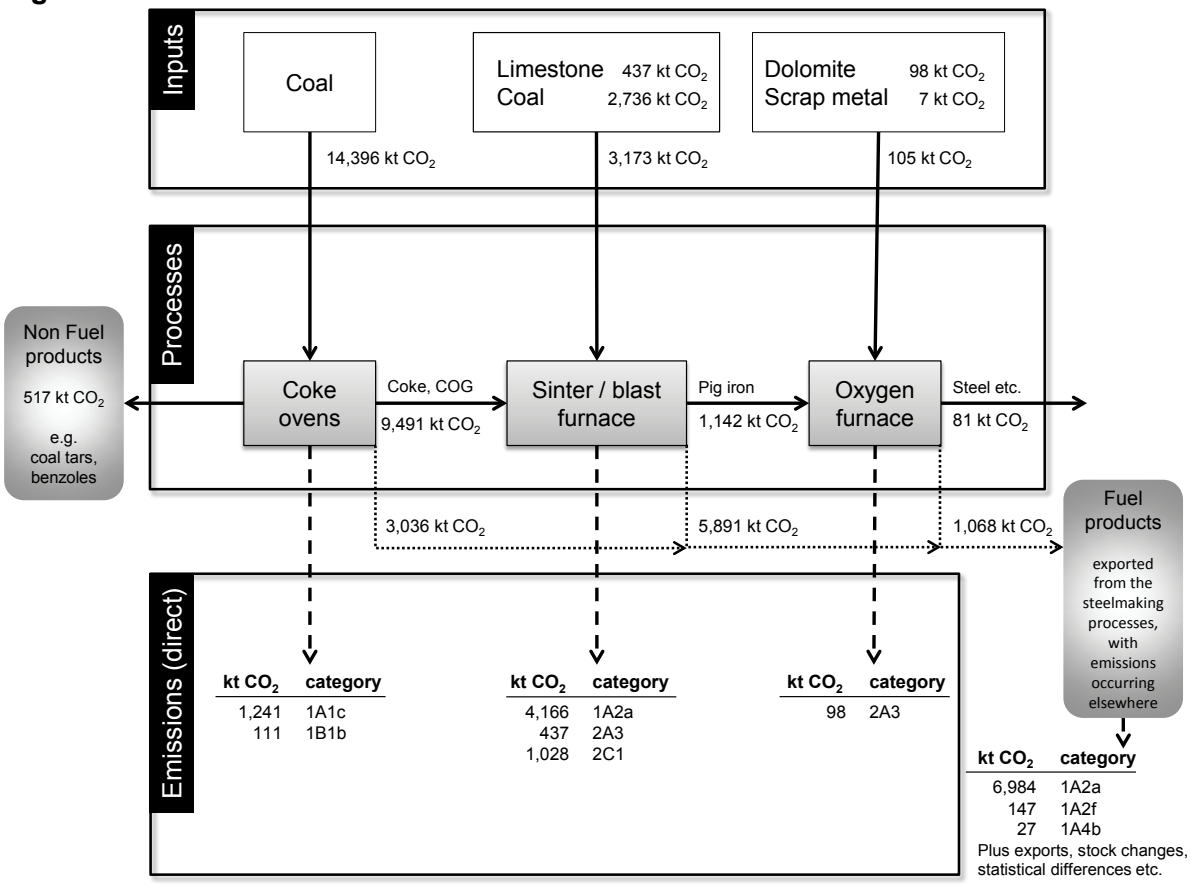
The carbon balance for the combined coke ovens and integrated steelmaking processes is more complex, and is based on tracking the carbon through 4 successive stages – cokemaking, sintering, pig iron production, and basic oxygen steel production. At each stage carbon is input as fuels and/or feedstocks; carbon leaves in products; is emitted to air or removed as waste products. The scheme given below, listing the main inputs and outputs is a simplified version of the model:

coal → coke + coke oven gas + benzoles & tars + fugitive carbon emission
coke + limestone + iron ore → sinter + carbon emission
sinter + coke + other reducing agents → pig iron + blast furnace gas
pig iron + scrap + dolomite → steel + slag + basic oxygen furnace gas

The outputs that are allowed to vary, and therefore used to ensure that the overall carbon balances, are coke, blast furnace gas and basic oxygen furnace gas.

The carbon balance model used is shown in a simplified form in **Figure 3-3**, with inputs and outputs of carbon (expressed as CO2) given for the year 2011 as an example.

Figure 3-3 Carbon balance model for 2011



Methods used to calculate emission estimates for indirect gases are summarised in **Table 3-12**.

Table 3-12 Methods for calculation of indirect greenhouse gas emission from 1A2

Sector/pollutant	CO	NO_x	SO_2	NMVOC
Cement (fuel combustion)	*[Emissions reported under 'non-decarbonising' – see below]*			
Cement (non-decarbonising)	The inventory agency uses data reported by operators to environmental regulators directly within the inventory.			
Lime Manufacture	Emissions data from regulator.		AD x EF	
Autogenerators – coal	Emissions data from regulator.			AD x EF
Autogenerators - gas	AD x EF			
Other Industry	AD x EF[1.]			
Chemicals	AD x EF[1.]			
Non-ferrous metals	AD x EF[1.]			
Food & drink	AD x EF[1.]			
Paper & printing	AD x EF[1.]			
Sinter Plant	Emissions estimates for individual sites provided by process operators.			
Chemical industry (soda ash)	Data from regulator.	No emissions		

[1]Emission estimated for NO_x based on a combination of reported data for large combustion plant and literature based emissions factors and fuel consumption for small plant.

In almost all cases, the inventory contains fuel-specific emission estimates of indirect gases for each sector, so, for example, there are emission estimates for coal burnt in chemical plants, as well as estimates for emissions from gas burnt. The sole exception to this is for cement kilns. This is because each kiln burns a mixture of fuels (often a blend of coal and petroleum coke, plus waste-derived fuels) and while emissions of carbon from each fuel can still be calculated, it is more realistic to calculate overall emissions for indirect greenhouse gases. Estimates for the four indirect gases are based on emissions data reported by operators and are presented as overall emissions rather than broken down by fuel.

There were no emissions observed in 1A2a-1A2e for any overseas territories or crown dependencies. Fuel consumption data from 1A2f was provided by each territory. These data do not necessarily cover the entire time series so interpolation and extrapolation was applied to produce a complete time series. UK GHGI emission factors were applied to these activity data for all sources.

3.2.10.2.2 Activity data used

The DUKES publication is used to obtain the relevant activity statistics, but with some additional data collected from industry in order to provide further detail or to improve on the detailed allocation of fuels to industry sector. As with elsewhere in the UK inventory, the fuel data used are consistent with the overall demand figures given in the UK energy statistics. DUKES provides most of the data needed to derive separate estimates of fuel usages by industry sector, which are reported under the six source categories 1A2a – 1A2f. This full breakdown is available for coal, natural gas, fuel oil and gas oil as data are available within DUKES. Other fuels such as LPG, coke and burning oil are reported solely under 1A2f due to a lack of any data on sectoral use in DUKES. Details of the detailed activity data are given in Annex 3 (Section A3.3.4.1).

Fuel consumption estimates from other data sources complement the DUKES data, and allow greater detail in the inventory. Fuel usage in ammonia production (1A2c) and cement kilns (1A2f) are collected from process operators, directly in the case of ammonia, via the Mineral Products Association (MPA) in the case of cement kilns. These data are not complete for all of the earlier part of the time series, so some assumptions have to be made to fill these gaps. For example, MPA data are not available for 1991-1999, and so fuel usage for these years must be interpolated between the 1990 and 2000 data, taking also into account changes in cement clinker production in each year. For ammonia production sites, data on gas usage and ammonia production are quite limited prior to 1998, and the estimates for 1990-1997 are largely based on extrapolation back from later reported data. All of the sites in operation in 1990 were still in operation in the late 1990s when data are available, so the extrapolation back to 1990 can be done at site-level, and with a high level of confidence since the capacity of these plants across the time series is known.

Data for autogenerators are taken directly from DUKES and relate to fuels used for electricity generation by companies primarily for their own consumption. The Inventory does not treat combined heat and power (CHP) differently to other installations. Hence CHP systems where all of the electricity is fed into the public supply are classified as power stations and CHP systems where electricity is used by the generator are classified as autogeneration. Emissions for autogenerators are reported under 1A2f.

For industrial and construction off-road machinery, emissions are reported under 1A2fii and are modelled based on a survey to obtain equipment population data for one year, and statistical data to create a full time series, combined with assumptions for hours of usage, equipment age and type, and power output. The method for calculating these emissions is

described in the Section on IPCC Categories 1A4, dealing with other off-road machinery, **Section 3.2.13**.

The reallocation of fuel activity data from UK energy statistics is required in some instances:

- to split out more detailed estimates for some industrial sectors such as ammonia, cement and lime. In these cases, the reallocation is merely between source categories that are reported under the same CRF category;
- to reconcile the inventory fuel data with other data for industrial users, such as fuel use estimates from cement kiln operators. In that case, the reallocation involves the transfer of fuel between categories within CRF 1A2;
- to reconcile the inventory fuel data with other data for fuel users outside the industrial sector, for example data from EU ETS for gas distributors, and process operators in the case of power stations. In these cases, the reallocations involve the transfer of fuel between 1A2 and other source categories i.e. 1A1 for the two examples given.
- Gas oil is used in many types of mobile machinery as well as off-road vehicles, ships, boats, and trains. Reallocations are needed to reconcile the gas oil estimates in the inventory with other activity data for these mobile machinery and transport sectors, i.e. data on populations of mobile equipment, or train or ship movements etc. DUKES does not separate out fuels used in off-road vehicles or mobile machinery and so reallocations of gas oil are necessary in the inventory in order to both provide separate estimates for gas oil use in stationary sources and mobile sources, and also to reconcile the inventory estimates with other data sources. The approach developed for allocating gas oil between different source categories is described in **Section 3.2.12.2**

Reallocations of fuels are necessary for burning oil, fuel oil, gas oil, natural gas, OPG and petroleum coke. The latter is a special case in that DUKES does not include estimates of petroleum coke use as an industrial fuel, instead treating it as being used for non-energy applications. The inventory estimates for petroleum coke use in 1A2f are therefore a reallocation of data from non-energy use in DUKES to 1A2. A similar reallocation has to be made for petroleum coke from non-energy use to 1A4. Reallocations in the inventory are described in **Annex 3.3**.

3.2.10.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type. The uncertainty in the activity data for fuel combustion sources is based on the statistical difference between supply and demand in DUKES, except for where the fuel total in the inventory deviates from the national total in DUKES (OPG, petroleum coke).

Most of the core activity data for this source category is derived from the DECC publication the Digest of UK Energy Statistics. **Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A. **Table 3-13** summarises the time series consistency of emission factors used in source category 1A2.

In general, emission factors are taken from a consistent source across the time series so few time series consistency issues arise. Some EU ETS data are used for coal-fired autogenerators and other large combustion plant such as lime kilns and the use of factors from Baggott *et al*, 2004 for the earlier part of the time series does result in a step change in

the factors for the period 2003-2005. In the case of lime kilns, the EU ETS-based factors show considerable variation over the period 2005-2011 and so the step change between non-ETS data in 2003 and ETS data in 2005 is considered an acceptable trend using the best available data for the source. For coal-fired autogeneration, the earlier factors are typically 5 to 10% higher; this may indicate that the time series of emission factors are inaccurate, or it may indicate that the impact of EU ETS has led to switching of fuel sources by the plant operators.

Table 3-13 Time series consistency of emission factors of direct GHGs used in source category 1A2

GHGs	Source category	Fuel types	Comments on time series consistency
Carbon	1A2	All fuels	EFs vary somewhat across time series based on comprehensive carbon factor review in 2004, with UKPIA providing new CEF data for many fuels used in this sector. Emission factors for coal use by autogenerators for 2005 onwards are now based on EU ETS data. Emission factors for lime kilns are also based on EU ETS data.
CH_4, N_2O	1A2	All fuels	Nearly all EFs are constant over the entire time series, with limited use of time-varying EFs due to fuel variability or technological developments.

3.2.10.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Allocations of fuel use are primarily derived from DECC publications that are subject to established QA/QC requirements, as required for all UK National Statistics. For specific industry sectors (iron & steel, cement, lime, autogeneration) the quality of these data are also checked by the Inventory Agency through comparison against operator-supplied information and unverified Emission Trading Scheme baseline datasets (covering 1998 to 2003). As discussed above, there have been instances where such information has led to amendments to fuel allocations reported by DECC (through fuel re-allocations between sectors).

3.2.10.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3-14** and emission factors in **Table 3-15** below. For information on the magnitude of recalculations to Source Category 1A2, see **Section 10**.

For the OTs and CDs, there have been recalculations to these emission estimates since the previous submission due to an improvement in the fuel density values used in the estimates. This led to an increase of 11% in emissions from Guernsey across the whole time series, however this is a very small change to total UK emissions.

Table 3-14 1A2 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
1A2a	Iron and steel - combustion plant	Fuel oil	0.11	0.11	0.11	0.06	Mt fuel consumed	DUKES activity data revised for 2009 onwards
		Gas oil	0.011	0.004	0.010	0.003	Mt fuel consumed	Gas oil allocation revised
	Sinter production	Coke	0.81	0.38	0.81	0.42	Mt fuel consumed	DUKES activity data revised for 2008 and 2010
1A2c	Ammonia production - combustion	Natural gas	108	94	108	96	Mth fuel consumed	Revised estimates for process/combustion split in gas use at one site.
		Natural gas	916	1144	916	1120	Mth fuel consumed	DUKES activity data revised for 2010
1A2d	Pulp, Paper and Print (combustion)	Natural gas	399	560	399	561	Mth fuel consumed	DUKES activity data revised for 2010
1A2e	Food & drink, tobacco (combustion)	Natural gas	678	817	678	809	Mth fuel consumed	DUKES activity data revised for 2010
	Lime production - non decarbonising	Coal	0.023	0.088	0.025	0.088	Mt fuel consumed	Minor revisions to the estimates of anthracite use in 2003-2006 and use of revised estimates for lime production to produce the estimates of coal and anthracite use for 1990-1998.
		Natural gas	56.3	44.3	61.1	44.3	Mth fuel consumed	Use of revised estimates for lime production to produce the estimates of gas use for 1990-1998.
	Other industrial combustion	Biomass			0.000	1.452	Mt fuel consumed	Review of biomass used following UNFCCC review found that additional biomass use as fuel needed to be included from UK energy statistics.
		Fuel oil	1.65	0.18	1.65	0.38	Mt fuel consumed	Changes in 2009 and 2010 largely reflect updates to UK energy statistics. Revisions for earlier years are due to other updates to assumptions such as the quantity of fuel oil reallocated from 1A2 to 1A1.
		Gas oil	1.05	0.08	1.04	0.07	Mt fuel consumed	Changes mainly due to minor revisions in the allocation of fuel between different industrial sectors rather than revisions to the total fuel burnt.
		Natural gas	2351	1535	2346	1535	Mth fuel consumed	Changes mainly due to minor revisions in the allocation of fuel between different industrial sectors rather than revisions to the total fuel burnt.

IPCC Category	Source Name	Activity Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
		OPG	123	92	536	587	Mth fuel consumed	Addition of estimates of emissions from combustion of by-products at ethylene crackers, following UNFCCC review.
	Autogenerators	Natural gas	95.8	545.8	95.8	580.0	Mth fuel consumed	Revisions to UK gas and electricity supply statistics
	Industrial off-road mobile machinery	Gas oil	2.03	1.54	2.03	1.55	Mt fuel consumed	Revisions to the sectoral-allocation of DERV and gas oil following a review of methodology for estimating these fuels.
	Autogeneration - exported to grid	Natural gas	36.2	442.0	36.2	471.0	Mth fuel consumed	Revisions to UK gas and electricity supply statistics

Table 3-15 1A2 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
1A2a	Blast furnaces	Carbon	Coke oven gas	1.17	1.18	1.17	1.18	kt C / Mth	Revisions to UK energy statistics which impact on the carbon balance approach used to calculate carbon factors for fuels used in steelworks
		CH4	LPG			0.0005	0.0005	kt / Mth	Emission factors for this fuel use not previously included.
		N2O	LPG			0.00001	0.00001	kt / Mth	Emission factors for this fuel use not previously included.
	Sinter production	Carbon	Coke	813.23	852.37	813.23	853.59	kt C / Mt	Revisions to UK energy statistics which impact on the carbon balance approach used to calculate carbon factors for fuels used in steelworks
		CH4	Coke	1.76	1.41	1.76	1.30	kt / Mt	Correction of error
	Iron and steel - combustion plant	Carbon	Blast furnace gas	7.93	8.58	7.93	8.19	kt C / Mth	Revisions to UK energy statistics which impact on the carbon balance approach used to calculate carbon factors for fuels used in steelworks
		Carbon	Coke	813.2	852.4	813.2	853.6	kt C / Mt	Revisions to UK energy statistics which impact on the carbon balance approach used to calculate carbon factors for fuels used in steelworks
1A2b	Non-Ferrous Metal (combustion)	Carbon	Coal	659.6	657.2	659.6	656.9	kt C / Mt	Minor change to calorific value for industrial coal, used to calculate emission factor for some years.

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
1A2c	Chemicals (combustion)	Carbon	Coal	659.6	657.2	659.6	656.9	kt C / Mt	Minor change to calorific value for industrial coal, used to calculate emission factor for some years.
1A2d	Pulp, Paper and Print (combustion)	Carbon	Coal	659.6	657.2	659.6	656.9	kt C / Mt	Minor change to calorific value for industrial coal, used to calculate emission factor for some years.
1A2e	Food & drink, tobacco (combustion)	Carbon	Coal	659.6	657.2	659.6	656.9	kt C / Mt	Minor change to calorific value for industrial coal, used to calculate emission factor for some years.
1A2f	Lime production - non decarbonising	Carbon	Coal	659.6	635.1	659.6	634.4	kt C / Mt	Minor revisions to analysis of EU ETS data used to generate this factor
		Carbon	Coke	813.2	852.4	813.2	853.6	kt C / Mt	Revisions to UK energy statistics which impact on the carbon balance approach used to calculate carbon factors for fuels used in steelworks
	Other industrial combustion	Carbon	Coal	659.6	657.2	659.6	656.9	kt C / Mt	Minor change to calorific value for industrial coal, used to calculate emission factor for some years.
		Carbon	Coke	813.2	852.4	813.2	853.6	kt C / Mt	Revisions to UK energy statistics which impact on the carbon balance approach used to calculate carbon factors for fuels used in steelworks
		CH4	Biomass	NA	NA	0.36	0.36	kt / Mt	Emission factors for this fuel use not previously included.
		N2O	Biomass	NA	NA	0.05	0.05	kt / Mt	Emission factors for this fuel use not previously included.
	Industrial off-road mobile machinery	CH4	DERV	0.18	0.18	0.16	0.15	kt / Mt	Correction to off-road model
		N2O	DERV	1.53	1.46	1.36	1.29	kt / Mt	
		CH4	Gas oil	0.18	0.17	0.16	0.15	kt / Mt	
		N2O	Gas oil	1.53	1.46	1.36	1.29	kt / Mt	

3.2.10.6 Source Specific Planned Improvements

Emission factors and activity data are kept under review. For full details of the improvement programme see **Section 1.2.2.5**.

3.2.11 Source Category 1A3 – Transport

3.2.11.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1A3a: Domestic Aviation	T3	CS, CR, D
	1A3b: Road Transport	T3	CS, CR
	1A3b: Railways (Freight)	T2	CS, CR
	Railways (Intercity)	T2	CS, CR
	Railways (Regional)	T2	CS, CR
	1A3d: National Navigation	T2, T3	CS, CR
	1A3e: Aircraft Support	T3	CS, CR
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	Mobile combustion-Road vehicles, CO_2 Mobile combustion-Road vehicles, N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from 1A3 included. All relevant UK Overseas Territories and Crown Dependencies emissions included within category totals within CRF submission – UK fuel based EFs used.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	New sources for navigation: vessel movements between UK and Overseas Territories Updated factors for N_2O from diesel trains (in line with EMEP/EEA Guidebook)		

Road transport is by far the largest contributor to transport emissions and estimations are made for a wide variety of vehicle types using petrol, diesel and LPG.

Emissions from vehicles running on natural gas are not estimated. The number of such vehicles in the UK is extremely small and there are no separate figures in DUKES on the amount of gas used by road transport, nor are there useable data on the total numbers of vehicles equipped to run on gas from vehicle licensing sources. The small amount of gas that is used in the road transport sector would currently be allocated to other sources in DUKES. Emissions of Greenhouse gases from vehicles running on LPG are included.

Methane and nitrous oxide emissions from road transport are calculated from traffic data and fuel consumption and include the contribution from the biofuel component of the fuels used.

The UK GHGI reports emissions from both stationary and mobile sources for railways. Stationary emissions are reported under category 1A4a. Mobile emissions, which are

reported under 1A3c cover estimates from diesel trains as freight, intercity and regional. Emissions from consumption of coal used to power steam trains are also included in the inventory.

Emission estimates from the navigation section (1A3d) cover coastal shipping, inland waterways and international marine. Emissions from vessel movements between the UK and Overseas Territories were estimated and included in the national totals for the first time. This was in response to recommendations from the UNFCCC Expert Review Team in 2012.

Emissions from aircraft support vehicles in airports are reported in 1A3e. Note that emissions from fuel combustion to run UK pipelines (e.g. use of natural gas to operate compressors on pipelines) are not reported explicitly within DUKES and the emissions from this fuel use are included within other source categories in the inventory. The use of natural gas in compressor stations for the UK natural gas transmission and distribution pipeline network is included within an aggregated fuel allocation in DUKES for "Other" energy industry use, and the emissions are reported in 1A1c (Gas production – downstream). The UK also includes a number of chemical pipeline systems, including a network of pipes to transfer petrochemical products such as ethylene between different production centres in Scotland and England. The emissions from fuel use to operate these pipelines are either allocated within 1A2c Chemical industry combustion where natural gas is used, or 1A1a Power generation where electricity is used to run compressors.

The UK does not include CH_4 or N_2O emissions from lubricants explicitly. However, as emissions arise from the unintended combustion of lubricants in the engine, then all exhaust emission factors will include the contribution of lubricants as well the main fuel to the pollutant emissions when the vehicles or engines were tested. Hence, the emissions of CH_4 and N_2O (and other air pollutants) from lubricants are included implicitly in the exhaust emissions for each engine and fuel type – and reported as IE in the CRF.

3.2.11.2 Methodological Issues

The following sections summarise and then provide greater detail in the methods used to estimate emissions for each transport category. The method used to calculate emissions from aircraft support vehicles is described in the Section on IPCC Categories 1A4, dealing with other off-road machinery, **Section 3.2.12.**

3.2.11.2.1 Aviation

In accordance with the agreed guidelines, the UK inventory contains estimates for both domestic and international civil aviation. Emissions from international aviation are recorded as a memo item, and are not included in national totals. Emissions from both the Landing and Take-Off (LTO) phase and the Cruise phase are estimated. A summary of the more detailed approach used is given below, and a full description is given in Watterson *et al.* (2004). The method used to estimate emissions from military aviation can be found towards the end of this section on aviation.

Emissions are estimated from the number of aircraft movements broken down by aircraft type at each UK airport, and so complies with the IPCC Tier 3 specification. Emissions of a range of pollutants are estimated in addition to the reported greenhouse gases. The method reflects differences between airports and the aircraft that use them. Emissions from additional sources (such as aircraft auxiliary power units) are also included.

A number of improvements have been made to the model over recent years, to include findings from UK specific research. These reports and model improvements are summarised below.

- The RASCO study (23 regional airports, with a 1999 case calculated from CAA movement data) carried out for the Department for Transport (DfT), and the published inventories for Heathrow, Gatwick and Stansted airports, commissioned by BAA and representative of the fleets at those airports. Emissions of NO_x and fuel use from the Heathrow inventory have been used to verify the results of this study.
- The Project for the Sustainable Development of Heathrow (PSDH) (DfT, 2006).
- For departures, this study made recommendations for revised thrust setting at take-off and climb-out as well as revised cut-back heights, and for arrivals, the PSDH made recommendations for revised reverse thrust setting and durations along with revised landing-roll times. Further recommendations related to: the effects of aircraft speed on take-off emissions; engine spool-up at take-off; the interpolation to intermediate thrust settings; hold times; taxiing thrust and times; engine deterioration and APU emission indices and running times.
- The outcomes of this study were incorporated into the 2007 inventory for Heathrow, and the 2008 inventory for all other airports.
- For the 2009 inventory flights between the UK and overseas territories have been included as domestic aviation. Previous inventories included flights from the UK to overseas territories as international aviation, recorded as a memo item. Flights from overseas territories to the UK were not included in previous inventories.
- For the 2010 inventory all flights originating from the overseas territories, irrespective of destination, have been included in the inventory as have return flights from oil rigs.

Reporting of aviation in the GHG inventory

Following IPCC methodology guidelines and UNFCCC reporting guidelines, emissions from civil aviation are divided into domestic aviation and international aviation. Domestic aviation (including take-off and landing, and cruise) is reported in category 1A3a and is included in the national total. International aviation is reported as a memo item. Estimates are also made of emissions from military aviation, these are reported under category 1A5b.

The UK CAA has provided the aircraft movement data used to estimate emissions from civil aviation. The definitions the CAA use to categorise whether a movement is international or domestic are (CAA, *per. comm.*)

- **Domestic**: A flight is domestic if the initial point on the service is a domestic and the final point is a domestic airport; and
- **International**: A flight is international if either the initial point or the final point on the service is an international airport.

Take, for example, a flight (service) that travels the following route: **Glasgow** (within the UK) – **Birmingham** (within the UK) – **Paris** (outside the UK). The airport reporting the aircraft movement in this example is Glasgow, and the final airport on the service is Paris. The CAA categorises this flight as international, as the final point on the service is outside the UK.

By following the IPCC Good Practice Guidance (IPCC, 2000), it is necessary to know whether passengers or freight are put down before deciding whether the whole journey is considered as an international flight or consisting of a (or several) domestic flight(s) and an

international flight. We feel the consequence of the difference between CAA and IPCC definitions will have a small impact on total emissions.

The CAA definitions above are also used by the CAA to generate national statistics of international and domestic aircraft movements. Therefore, the aircraft movement data used in this updated aviation methodology are consistent with national statistical datasets on aircraft movements.

In order to ensure complete geographical coverage of the UK for the purposes of reporting to the UNFCCC, some reallocations are made to the CAA data.
Flights between the UK and the CDs are considered to be within the UK in the CAA aircraft movement data, therefore no modifications are required for these flights, except for when calculating emissions for EUMM or UK only reporting.

Fights between the UK and the OTs are considered to be international in the CAA aircraft movement data, but have been reclassified as domestic aviation since the 2009 inventory. Flights between overseas territories (obtained from the DfT data) have been classed as domestic aviation. Other flights originating from the overseas territories have been classed as international.

Total modelled fuel use is normalised to the total in DUKES. The total in DUKES includes all flights originating from the UK and CDs, therefore flights from the OTs are additional to this total and are excluded from the normalisation.

Aircraft Movement Data (Activity Data)

The methods used to estimate emissions from aviation require the following activity data:

- **Aircraft movements and distances travelled**
  Detailed activity data has been provided by the UK Civil Aviation Authority (CAA). These data include aircraft movements broken down by: airport; aircraft type; whether the flight is international or domestic; and, the next/last POC (port of call) from which sector lengths (great circle) have been calculated. The data covered all Air transport Movements (ATMs) excluding air-taxi.

  Fights between the UK and overseas territories are considered to be international in the CAA aircraft movement data, but these have been reclassified as domestic aviation.

  The CAA also compiles summary statistics at reporting airports, which include air-taxi and non-ATMs.

  The CAA data have been supplemented with data from overseas territories, supplied by DfT.

  A summary of aircraft movement data is given in **Table 3-16.** Fights between the UK and overseas territories are included in domestic.

- **Inland Deliveries of Aviation Turbine Fuel and Aviation Spirit**
  Total inland deliveries of aviation spirit and aviation turbine fuel to air transport are given in DUKES (DECC 2012). This is the best approximation of aviation bunker fuel consumption available and is assumed to cover international, domestic and military use.

- **Consumption of Aviation Turbine Fuel and Aviation Spirit by the Military**
  Historically, total consumption by military aviation has been given in ONS (1995) and MOD (2005a) and was assumed to be aviation turbine fuel. A revised, but consistent time series of military aviation fuel was provided by the Safety, Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2009 and 2010) covering each financial year from 2003/04 to 2009/10. These data also included estimates of aviation spirit and fuel classed as "Casual Uplift", with the latter being drawn from commercial airfields world-wide and assumed not to be included in DUKES. In 2011 the MoD revised their methodology for calculating fuel consumption, which provided revised data for 2008/09 onwards (MoD 2011). These data no longer separately identified aviation spirit or fuel classed as "Casual Uplift", so all fuel was assumed to be aviation turbine fuel and included in DUKES.

  Adjustments were made to the data to derive figures on a calendar year basis.

Table 3-16 Aircraft Movement Data

	International LTOs (000s)	Domestic LTOs (000s)	International Aircraft, Gm flown	Domestic Aircraft, Gm flown
1990	469.62	367.81	654.15	114.21
1991	454.57	335.27	643.25	106.58
1992	491.80	351.97	725.80	111.69
1993	502.90	362.83	737.68	116.63
1994	519.22	342.45	811.29	111.59
1995	540.74	355.42	851.62	115.64
1996	570.15	366.32	892.50	120.65
1997	595.78	377.38	969.19	125.89
1998	632.18	383.30	1053.96	132.72
1999	666.83	387.90	1120.39	136.25
2000	713.04	398.40	1193.15	142.70
2001	720.51	414.16	1208.59	153.50
2002	712.98	415.33	1200.17	152.65
2003	729.00	423.56	1251.83	155.59
2004	762.36	458.69	1356.88	166.59
2005	804.39	484.29	1448.79	177.51
2006	831.40	486.48	1517.07	179.36
2007	857.85	480.82	1572.29	175.79
2008	844.41	467.96	1558.33	172.23
2009	776.37	417.48	1441.29	156.38
2010	736.93	390.92	1396.04	145.40
2011	774.95	372.97	1486.65	141.92

Notes

Gm Giga metres, or 10^9 metres

Estimated emissions from aviation are based on data provided by the CAA and, for overseas territories, the DfT.

Gm flown calculated from total flight distances for departures from UK and overseas territories airports.

3.2.11.2.2 Emission factors used

The following emission factors were used to estimate emissions from aviation. The emissions of CO_2, SO_2 and metals depend on the carbon, sulphur and metal contents of the aviation fuels'. Emissions factors for CO_2, SO_2 and metals have been derived from the contents of carbon, sulphur and metals in aviation fuels. These contents are reviewed, and revised as

necessary, each year. Full details of the emission factors used are given in Watterson *et al*. (2004).

Table 3-17 CO_2 and SO_2 Emission Factors for Civil and Military Aviation for 2011 (kg/t)

Fuel	CO_2	SO_2
Aviation Turbine Fuel	859	0.88
Aviation Spirit	853	0.88

Notes

Carbon and sulphur contents of fuels provided by UKPIA (2012)
Carbon emission factor as kg carbon/tonne
Military aviation only uses ATF

For the LTO-cycle calculations, emissions per LTO cycle are required for each of a number of representative aircraft types. Emission factors for the LTO cycle of aircraft operation have been calculated from the International Civil Aviation Organization (ICAO) database. The cruise emissions have been taken from CORINAIR data (which are themselves developed from the same original ICAO dataset).

Table 3-18 Average Non-CO_2 Emission Factors for Civil and Military Aviation - 2011

	Fuel	Units	CH_4	N_2O	NO_x	CO	NMVOC
Civil aviation							
Domestic LTO	AS	kt/Mt	1.55	0.10	3.78	1077.01	12.64
Domestic Cruise	AS	kt/Mt	-	0.10	7.39	2.54	0.18
Domestic LTO	ATF	kt/Mt	0.19	0.10	12.70	8.69	1.76
Domestic Cruise	ATF	kt/Mt	-	0.10	14.40	2.40	0.51
International LTO	AS	kt/Mt	1.79	0.10	2.19	1228.37	14.55
International Cruise	AS	kt/Mt	-	0.10	7.13	0.84	0.03
International LTO	ATF	kt/Mt	0.13	0.10	13.89	8.87	1.20
International Cruise	ATF	kt/Mt	-	0.10	14.10	1.16	0.52
Military aviation	ATF	kt/Mt	0.10	0.10	8.50	8.20	1.00

Notes

AS – Aviation Spirit

ATF – Aviation Turbine Fuel

Use of all aviation spirit assigned to the LTO cycle

Method used to estimate emissions from the LTO cycle – civil aviation – domestic and international

The basic approach to estimating emissions from the LTO cycle is as follows. The contribution to aircraft exhaust emissions (in kg) arising from a given mode of aircraft operation (see list below) is given by the product of the duration (seconds) of the operation, the engine fuel flow rate at the appropriate thrust setting (kg fuel per second) and the emission factor for the pollutant of interest (kg pollutant per kg fuel).

The annual emissions total for each mode (kg per year) is obtained by summing contributions over all engines for all aircraft movements in the year. The time in each mode of operation for each type of airport and aircraft has been taken from individual airport

studies. The time in mode is multiplied by an emission rate (the product of fuel flow rate and emission factor) at the appropriate engine thrust setting in order to estimate emissions for phase of the aircraft flight. The sum of the emissions from all the modes provides the total emissions for a particular aircraft journey. The modes considered are:

- Taxi-out;
- Hold;
- Take-off Roll (start of roll to wheels-off);
- Initial-climb (wheels-off to 450 m altitude);
- Climb-out (450 m to 1000 m altitude);
- Approach (from 1000 m altitude);
- Landing-roll;
- Taxi-in;
- APU use after arrival; and
- Auxiliary Power Unit (APU) use prior to departure.

Departure movements comprise the following LTO modes: taxi-out, hold, take-off roll, initial-climb, climb-out and APU use prior to departure.

Arrivals comprise: approach, landing-roll, taxi-in and APU use after arrival.

Method used to estimate emissions in the cruise – civil aviation – domestic and international

The approaches to estimating emissions in the cruise are summarised below. Cruise emissions are only calculated for aircraft departures from UK airports (emissions therefore associated with the departure airport), which gives a total fuel consumption compatible with recorded deliveries of aviation fuel to the UK. This procedure prevents double counting of emissions allocated to international aviation.

Estimating emissions of the indirect and non-greenhouse gases

The EMEP/CORINAIR Emission Inventory Guidebook (EMEP/CORINAIR, 1996) provides fuel consumption and emissions of non-GHGs (NO_x, HC and CO) for a number of aircraft modes in the cruise. The data are given for a selection of generic aircraft type and for a number of standard flight distances.

The breakdown of the CAA movement by aircraft type contains a more detailed list of aircraft types than in the EMEP/CORINAIR Emission Inventory Guidebook. Therefore, each specific aircraft type in the CAA data has been assigned to a generic type in the Guidebook. Details of this mapping are given in Watterson *et al*. (2004).

A linear regression has been applied to these data to give emissions (and fuel consumption) as a function of distance:

$$E_{Cruise_{d,g,p}} = m_{g,p} \times d + c_{g,p}$$

Where:

$E_{Cruise_{d,g,p}}$	is the emissions in cruise of pollutant p for generic aircraft type g and flight distance d (kg)
d	is the flight distance
g	is the generic aircraft type
p	is the pollutant (or fuel consumption)

$m_{g,p}$ is the slope of regression for generic aircraft type g and pollutant p (kg / km)

$c_{g,p}$ is the intercept of regression for generic aircraft type g and pollutant p (kg)

Emissions of SO_2 and metals are derived from estimates of fuels consumed in the cruise (see equation above) multiplied by the sulphur and metals contents of the aviation fuels for a given year.

Estimating emissions of the direct greenhouse gases

Estimates of CO_2 were derived from estimates of fuel consumed in the cruise (see equation above) and the carbon contents of the aviation fuels.

Methane emissions are believed to be negligible at cruise altitudes, and the emission factors listed in EMEP/CORINAIR guidance are zero (EMEP/CORINAIR, 1996); we have also assumed them to be zero. This was the assumption in the previous aviation calculation method also.

Estimates of N_2O have been derived from an emission factor recommended by the IPCC (IPCC, 1997) and the estimates of fuel consumed in the cruise (see equation above).

Overview of method to estimate emission from military aviation

LTO data are not available for military aircraft movements, so a simple approach is used to estimate emissions from military aviation. A first estimate of military emissions is made using military fuel consumption data and IPCC (1997) and EMEP/CORINAIR (1999) cruise defaults shown in Table 1 of EMEP/CORINAIR (1999) (see **Table 3-18)**. The EMEP/CORINAIR (1999) factors used are appropriate for military aircraft. The military fuel data include fuel consumption by all military services in the UK. It also includes fuel shipped to overseas garrisons, casual uplift at civilian airports.

Emissions from military aircraft are reported under IPCC category 1A5 Other.

Fuel reconciliation

The estimates of aviation fuels consumed in the commodity balance table in the DECC publication DUKES are the national statistics on fuel consumption, and IPCC guidance states that national total emissions must be on the basis of fuel sales. Therefore, the estimates of emissions have been re-normalised based on the results of the comparison between the fuel consumption data in DUKES and the estimate of fuel consumed produced from the civil aviation emissions model, having first scaled up the emissions and fuel consumption to account for air-taxi and non-ATMs. The scaling is done separately for each airport to reflect the different fractions of air-taxi and non-ATMs at each airport and the different impacts on domestic and international emissions. The aviation fuel consumptions presented in DECC DUKES include the use of both civil and military fuel, and the military fuel use must be subtracted from the DUKES total to provide an estimate of the civil aviation consumption. This estimate of civil aviation fuel consumption has been used in the fuel reconciliation. Emissions from flights originating from the overseas territories have been excluded from the fuel reconciliation process as the fuel associated with these flights is not included in DUKES. Emissions will be re-normalised each time the aircraft movement data is modified or data for another year added.

3.2.11.2.3 Road transport (1A3b)

The following is a summary of the methods used to develop the inventory for road transport and recalculations and methodological changes made in the 2013 submission of the inventory:

Summary of Methodology

A Tier 3 methodology is used for calculating exhaust emissions from passenger cars (1A3bi), light goods vehicles (1A3bii), heavy duty vehicles including buses and coaches (1A3biii) and motorcycles (1A3biv). A Tier 2 methodology is used for calculating evaporative emissions (1A3bv) from petrol vehicles.

Summary of emission factors

There are a number of sources: COPERT 4, EMEP/EEA Emission Inventory Guidebook and UK specific emission factors as developed by Transport Research Laboratory (TRL) on behalf of the UK Department for Transport (DfT).

Summary of activity data

Traffic activity data in billion vehicle km by vehicle type are provided by DfT and total fuel sales for petrol and diesel are provided in the Digest of UK Energy Statistics (DUKES). Vehicle licensing statistics and on-road Automatic Number Plate Recognition data provided by DfT are used to further break down the vehicle km travelled by fuel type and vehicle year of first registration.

Details of methodology

Fuel-based emissions

Emissions of CO_2 and SO_2 from road transport are calculated from the consumption of petrol and diesel fuels and the sulphur content of the fuels consumed. Data on petrol and diesel fuels consumed by road transport in the UK are taken from the Digest of UK Energy Statistics published by the DECC and corrected for consumption by off-road vehicles and the very small amount of fuel consumed by the Crown Dependencies included in DUKES (emissions from the Crown Dependencies are calculated elsewhere).

In 2011, 13.90 Mt of petrol and 20.99 Mt of diesel fuel (DERV) were consumed in the UK. Petrol consumption has gone down while diesel consumption has increased as compared with 2010. It was estimated that of this, around 2.8% of petrol was consumed by inlands waterways and off-road vehicles and machinery and 0.5% used in the Crown Dependencies, leaving 13.45 Mt of petrol consumed by road vehicles in the UK in 2011. Around 1.8% of road diesel is estimated to be used by inland waterways and off-road vehicles and machinery (the bulk of these use gas oil), and 0.2% used in the Crown Dependencies, leaving 20.56 Mt of diesel consumed by road vehicles in the UK in 2011.

According to figures in DUKES (DECC, 2012), 0.098 Mt of LPG were used for transport in 2011, a reduction from 0.106 Mt the previous year.

Since 2005, there has been a rapid growth in consumption of biofuels in the UK. These are not included in the totals presented above for petrol and diesel which according to DECC refer only to mineral-based fuels (fossil fuels). According to statistics in DUKES and from HMRC (2012), 0.52 Mt bioethanol and 0.82 Mt biodiesel were consumed in the UK in 2011. On a volume basis, this represents about 3.3% of all petrol and 3.6% of all diesel sold in the UK, respectively, and on an energy basis it is estimated that consumption of bioethanol and biodiesel displaced around 0.310 Mt of mineral-based petrol (about 2.2% of total petrol that would have been consumed) and 0.715 Mt of mineral-based diesel (about 3.4% of total

diesel that would have been consumed). The CO_2 emissions arising from consumption of these fuels are not included in the national totals.

Emissions of CO_2, expressed as kg carbon per tonne of fuel, are based on the carbon content (by mass) of the fuel; emissions of SO_2 are based on the sulphur content of the fuel. Values of the fuel-based emission factors for CO_2 and SO_2 from consumption of petrol and diesel fuels are shown in **Table 3-19.** Values for SO_2 vary annually as the sulphur-content of fuels change, and are shown in for 2011 fuels based on data from UKPIA (2012).

Table 3-19 Fuel-Based Emission Factors for Road Transport (kg/tonne fuel)

Fuel	C[a]	SO_2[b]
Petrol	855	0.010
Diesel	863	0.015

a Emission factor in kg carbon/tonne, based on UKPIA (2005)

b 2011 emission factor calculated from UKPIA (2012) – figures on the weighted average sulphur-content of fuels delivered in the UK in 2011

Emissions of CO_2 and SO_2 can be broken down by vehicle type based on estimated fuel consumption factors and traffic data in a manner similar to the traffic-based emissions described below for other pollutants.

To distribute fuel consumption, hence emissions, between different vehicle types, a combination of data sources and approaches were used making best use of all available information.

Fuel consumption factors for petrol and diesel vehicles

Equations relating fuel consumption to average speed are based on the relationships for detailed categories of vehicles compiled by TRL on behalf of DfT. The factors themselves are available at http://www.dft.gov.uk/publications/road-vehicle-emission-factors-2009/ together with appropriate documentation from TRL on how the emission factors were derived (see for example the report by Boulter et al. (2009) at http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/report-3.pdf). The TRL equations were derived from their large database of emission measurements compiled from different sources covering different vehicle types and drive cycles. The measurements were made on dynamometer test facilities under simulated real-world drive cycles.

For cars, LGVs and motorcycles, the speed-related fuel consumption factors in g fuel/km were used in combination with average speed, fleet composition and vehicle km data for different road types as described below. The fleet-average fuel consumption factors calculated for these vehicle types grouped into their respective Euro emission standards are shown in **Table 3-20** for average speeds on urban, rural and motorway roads. The different emission standards are described in a later section.

Table 3-20 Fuel Consumption Factors for Light Vehicles (in g fuel/km)

g fuel /km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	66.4	62.8	69.1
	Euro 1	61.4	57.9	64.1
	Euro 2	58.8	55.3	61.5
	Euro 3	55.0	51.4	57.6

g fuel /km		Urban	Rural	Motorway
	Euro 4	50.8	47.2	53.4
	Euro 5	44.7	41.2	47.4
Diesel cars	Pre-Euro 1	60.3	55.0	61.2
	Euro 1	58.5	53.2	59.4
	Euro 2	54.9	49.6	55.8
	Euro 3	50.2	44.9	51.1
	Euro 4	47.7	42.4	48.7
	Euro 5	42.0	36.7	42.9
Petrol LGVs	Pre-Euro 1	68.7	64.1	70.0
	Euro 1	63.6	59.0	64.8
	Euro 2	60.9	56.3	62.1
	Euro 3	57.1	52.5	58.3
	Euro 4	52.3	47.7	53.6
	Euro 5	46.9	42.2	48.2
Diesel LGV	Pre-Euro 1	61.9	68.4	91.9
	Euro 1	76.7	84.4	110.1
	Euro 2	71.5	77.5	106.0
	Euro 3	63.2	69.8	104.0
	Euro 4	63.2	69.8	104.0
	Euro 5	63.2	69.8	104.0
Mopeds, <50cc, 2st	Pre-Euro 1	25.5		
	Euro 1	15.3		
	Euro 2	12.3		
	Euro 3	10.7		
Motorcycles, >50cc, 2st	Pre-Euro 1	27.5	30.2	
	Euro 1	25.3	27.8	
	Euro 2	25.3	27.8	
	Euro 3	25.3	27.8	
Motorcycles, >50cc, 4st	Pre-Euro 1	35.3	35.1	53.9
	Euro 1	33.5	33.2	46.9
	Euro 2	31.6	31.9	49.3
	Euro 3	31.6	31.9	49.3

For HGVs, the DfT provide statistics from a survey of haulage companies on the average miles per gallon (mpg) fuel efficiency of different sizes of lorries (DfT, 2011a). A time-series of mpg figures from 1989 to 2010 is provided by the road freight statistics and these can be converted to g fuel per kilometre fuel consumption factors. The figures will reflect the operations of haulage companies in the UK in terms of vehicle load factor and typical driving cycles, e.g. distances travelled at different speeds on urban, rural and motorway roads. The shape of the DfT/TRL speed-related functions based on test cycle measurements of more limited samples of vehicles are then used to define the variation, relative to the averaged value, in fuel consumption factor with speed and hence road type. It should be noted that the

publication of the road freight statistics was delayed in 2012 and hence mpg factors for 2011 were not available in time for the inventory compilation. Data for overall fuel efficiency of HGVs in 2010 from DfT has been assumed for 2011.

Table 3-21 presents the fleet-averaged fuel consumption factors for rigid and articulated HGVs from 1990-2011 for urban, rural and motorway conditions based on the road freight statistics published in DfT (2011a).

Table 3-21 Average fuel consumption factors for HGVs (in g fuel/km) in the fleet based on DfT's road freight statistics

g fuel/km	Rigid HGVs			Artic HGVs		
	Urban	Rural	Motorway	Urban	Rural	Motorway
1990	272.4	217.7	231.5	438.8	337.1	343.6
1991	276.6	221.0	235.1	437.2	335.9	342.4
1992	277.0	221.4	235.4	433.9	333.3	339.8
1993	266.9	213.5	227.0	412.1	316.7	322.8
1994	259.0	207.8	221.1	405.1	311.6	317.6
1995	263.3	212.2	225.9	395.5	304.6	310.5
1996	258.2	209.0	222.8	388.1	299.3	305.1
1997	256.3	208.4	222.3	387.2	299.2	304.9
1998	245.1	200.5	214.1	370.8	287.2	292.7
1999	249.8	205.4	219.6	370.3	287.3	292.8
2000	247.8	204.8	219.2	370.2	287.7	293.2
2001	259.8	214.2	228.8	375.5	292.0	297.6
2002	252.9	208.4	222.3	373.2	290.0	295.6
2003	262.8	216.1	230.1	378.3	293.7	299.4
2004	253.9	208.6	221.8	365.0	283.2	288.7
2005	250.7	205.0	217.4	360.9	279.7	285.2
2006	261.9	213.1	225.5	363.4	281.4	286.9
2007	270.1	218.5	230.7	365.9	283.1	288.7
2008	279.6	226.0	238.5	379.8	293.5	299.3
2009	281.8	228.0	240.8	381.1	294.3	300.1
2010	285.3	229.9	242.5	384.9	296.9	302.7
2011	284.8	229.2	241.7	384.1	296.0	301.8

For buses and coaches, the principal data source used was figures from DfT on the Bus Service Operators Grant system (BSOG). This is an audited subsidy, directly linked to the fuel consumed on local bus services. From BSOG financial figures, DfT were able to calculate the costs and hence quantity of fuel (in litres) used for local bus services going back to 1996 and using additional bus km data were able to derive implied fuel consumption factors for local service buses (DfT, 2012b). DfT believe this provides a relatively robust estimation of fuel consumption on local bus services and would be based on a larger evidence base than the DfT/TRL speed-related functions which are derived from a relatively small sample of buses and coaches tested. The BSOG data also take into account of fuel

consumption on local bus services that were carried out on dead mileage, i.e. mileage to and from the start and end of a bus route. In terms of trend, the BSOG data imply a continual increase in the average fuel consumption factor for local buses, i.e. a reduction in fuel efficiency over the period from 1998/9 to 2009/10. However, there is a small improvement in fuel efficiency between 2009/10 and 2010/11.

The BSOG data were used to define the fuel consumption factor for buses in the inventory over an urban cycle. However, the BSOG data do not cover rural bus services and coaches. For these, an approach similar to that used for HGVs was adopted by utilising the research-based, speed-related fuel consumption factors given by DfT/TRL in combination with the BSOG data. Using a combination of fleet composition data for different sizes of buses, the DfT/TRL functions were used to define how the fuel efficiency of the average bus and coach in the UK fleet varied with average speed and road type and year. The differences relative to the fuel efficiency factor for the average bus over an urban cycle were derived for the average bus on a rural cycle and the average coach on motorways. The relative differences were then applied to the BSOG-based urban bus factor to develop a series of internally consistent trends in bus and coach fuel consumption factor on urban, rural and motorway roads.

The BSOG data are provided on a financial year basis, the most recent being for 2010/11. The financial year figures were used to represent the factors for the earlier calendar year. Hence, the 2010/11 figures were used for the 2010 calendar year and superseded estimates for 2010 made last year when these data were not available. As there are no corresponding BSOG data to use for 2011, factors were estimating based on trends in the average fuel consumption factor for urban buses implied by DfT/TRL speed functions for different bus classes and the change in the bus fleet between 2010 and 2011. This produced a fuel efficiency scaling factor that could be applied to the factor for 2010.

Table 3-22 presents the fleet-averaged fuel consumption factor for buses and coaches from 1990-2011 for urban, rural and motorway conditions based on this method.

Table 3-22 Average fuel consumption factors for buses and coaches (in g fuel/km) in the fleet based on DfT's BSOG data

g fuel/km	Urban	Rural	Motorway
1990	268.9	167.8	190.9
1991	268.9	167.8	190.9
1992	268.9	167.8	190.9
1993	268.2	167.5	190.5
1994	265.0	165.7	189.0
1995	260.8	163.3	187.0
1996	255.9	160.7	184.8
1997	255.3	160.9	185.8
1998	255.1	161.5	187.4
1999	264.5	168.2	195.9
2000	277.0	176.7	206.4
2001	278.3	177.9	208.4
2002	290.0	186.1	219.0
2003	303.9	195.0	229.8
2004	309.5	198.6	234.1

g fuel/km	Urban	Rural	Motorway
2005	324.4	208.1	245.6
2006	319.2	204.7	241.6
2007	327.6	209.7	247.7
2008	340.7	217.8	257.3
2009	341.6	217.9	257.7
2010	338.0	215.2	254.8
2011	337.8	214.8	254.4

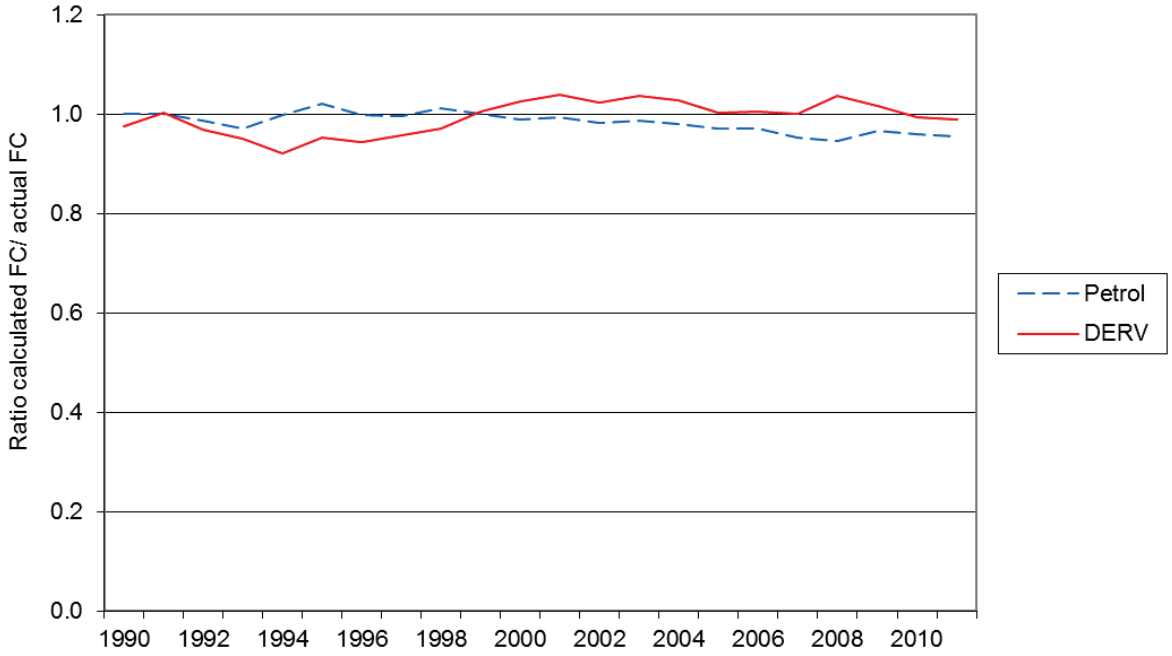
Fuel reconciliation and normalisation

A model is used to calculate total petrol and diesel consumption by combining these factors with relevant traffic data (as described below for hot exhaust emissions). These "bottom-up" calculated estimates of petrol and diesel consumption are then compared with DECC figures for total fuel consumption in the UK published in DUKES, adjusted for the small amount of consumption by inland waterways, off-road machinery and consumption in the Crown Dependencies.

The bottom-up estimated fuel consumption differs from the DUKES-based figures and so it is necessary to adjust the calculated estimates for individual vehicle types by using a normalisation process to ensure the total consumption of petrol and diesel equals the DUKES-based figures. This is to comply with the UNFCCC reporting system which requires emissions of CO_2 to be based on fuel sales.

Figure 3-4 shows the ratio of model calculated fuel consumption to the figures in DUKES based on total fuel sales of petrol and diesel in the UK, allowing for off-road consumption. For a valid comparison with DUKES, the amount of petrol and diesel displaced by biofuel consumption has been used to correct the calculated consumption of petrol and diesel. The ratio fluctuates just above and below the 1 line, but the difference is never higher than 8%. In 2011, the bottom-up method underestimates petrol and diesel consumption by 4.5% and 1.2% respectively. This is considered well within the uncertainty of the factors used to derive the bottom-up estimates.

Figure 3-4 Ratio of calculated fuel consumption to the DUKES fuel consumption



Note: Calculated petrol and diesel fuel consumption are based on traffic movement and fuel consumption factors summed for different vehicle types. DUKES figures for these fuels are based on fuel sales in the UK

The normalisation process introduces uncertainties into the fuel consumption and hence CO_2 emission estimates for individual vehicle classes even though the totals for road transport are known with high accuracy.

For petrol, the fuel consumption calculated for each vehicle type consuming petrol is scaled up or down by the same proportion to make the total petrol consumption align with DUKES. So for example, the fuel consumption estimated for petrol cars, LGVs and motorcycles are all increased by 4.5% to align with fuel sales in 2011. Cars consume the vast majority of this fuel, so the DUKES figures provide a relatively accurate description of the trends in fuel consumption and CO_2 emissions by petrol cars. A small residual is consumed by petrol LGVs and motorcycles, so their estimates are susceptible to fairly high levels of uncertainty introduced by the normalisation process.

For diesel, a number of different vehicle classes (cars, LGVs, HGVs and buses) all consume similar amounts of fuel. Either the fuel consumption for all diesel vehicles can be scaled to align with DUKES, as carried out for petrol normalisation, or consumption for specific vehicle types can be adjusted to bring the total in line with DUKES. Because all vehicle types make a similar contribution to diesel consumption, adjusting the calculated figures for all vehicle types by scaling can lead to distorted trends in the figures for specific vehicle types over a time-series.

After discussions with officials at DfT, it was decided to retain the consumption for diesel cars, LGVs and buses at the values calculated by the bottom-up approach and use HGVs to "carry the burden" of bringing the total diesel consumption in line with DUKES (DfT, 2009a). There were two main reasons for this. First, because HGVs are the largest overall consumer of diesel, this approach of correcting for the difference between calculated diesel consumption and fuel sales figures from DUKES has a smaller effect on HGVs than other

vehicle classes. A second reason is that a rationale can be given for HGVs leading to the overestimation of diesel consumption compared with sales since 1998 on the basis of "fuel tourism" effects. This is where vehicles consume fuel on UK roads that was purchased abroad. In this case, the fuel would not appear in the UK sales figures, but would be represented in consumption figures calculated from traffic movement data. Given the recent price differential between diesel sold in the UK and the rest of Europe and the amount of cross-border haulage operations, HGVs are believed to make a larger contribution to potential fuel tourism effects than any other class of vehicle. Furthermore, DfT were able to provide some data to back up this hypothesis. This included DfT estimates of the amount of fuel purchased abroad by UK vehicles and the kilometres travelled in the UK by foreign vehicles (DfT, 2009a). The 2009 figures suggested the total amount of fuel purchased abroad (and therefore not contributing to UK fuel sales in DUKES) by HGVs operating in the UK could be around 550 ktonnes compared with a gap of around 652 ktonnes in the estimate of total diesel consumption and the figures based on fuel sales in DUKES. This is at least consistent with a theory indicating HGV fuel tourism contributing to the gap and partial justification for adjusting the bottom-up estimated diesel consumption for HGVs to bring the total diesel consumption in line with DUKES. However, it is important to recognise that other factors including modelling uncertainty will also be playing a factor.

Emissions from LPG consumption

Total CO_2 emissions from vehicles running on LPG are estimated on the basis of national figures (from DUKES) on the consumption of this fuel by road transport. The CO_2 emissions from LPG consumption cannot be broken down by vehicle type because there are no reliable figures available on the total number of vehicles or types of vehicles running on this fuel. This is unlike vehicles running on petrol and diesel where the DfT has statistics on the numbers and types of vehicles registered as running on these fuels. It is believed that many vehicles running on LPG are cars and vans converted by their owners and that these conversions are not necessarily reported to vehicle licensing agencies. Figures from DUKES suggest that the consumption of LPG is around 0.3% of the total amount of petrol and diesel consumed by road transport and vehicle licensing data suggest around 0.4% of all light duty vehicles run on LPG in 2011.

Emissions of CO_2 from LPG consumption are calculated from total consumption figures and carbon factors for LPG fuel.

Emissions of CH_4 and N_2O from LPG consumption are calculated using traffic-based emission factors as described in following sections.

Emissions from natural gas consumption

The UK inventory does not currently estimate emissions from vehicles running on natural gas. The number of such vehicles in the UK is extremely small, with most believed to be running in captive fleets on a trial basis in a few areas. Estimates are not made as there are no separate figures from DECC on the amount of natural gas used by road transport, nor are there useable data on the total numbers and types of vehicles equipped to run on natural gas from vehicle licensing sources. The small amount of gas that is used in the road transport sector would currently be allocated to other sources in DUKES.

3.2.11.2.4 Traffic-based emissions

Emissions of the pollutants CH_4, N_2O, NMVOCs, NO_x, CO and other air pollutants are calculated from measured emission factors expressed in grammes per kilometre and road traffic statistics from the Department for Transport. The emission factors are based on experimental measurements of emissions from in-service vehicles of different types driven

under test cycles with different average speeds. The road traffic data used are vehicle kilometre estimates for the different vehicle types and different road classifications on the UK road network. These data have to be further broken down by composition of each vehicle fleet in terms of the fraction of diesel- and petrol-fuelled vehicles on the road and in terms of the fraction of vehicles on the road made to the different emission regulations which applied when the vehicle was first registered. These are related to the age profile of the vehicle fleet in each year.

Emissions from motor vehicles fall into several different categories, which are each calculated in a different manner. These are hot exhaust emissions, cold-start emissions and evaporative emissions of NMVOCs.

Hot exhaust emissions

Hot exhaust emissions are emissions from the vehicle exhaust when the engine has warmed up to its normal operating temperature. Emissions depend on the type of vehicle, the type of fuel its engine runs on, the driving profile of the vehicle on a journey and the emission regulations which applied when the vehicle was first registered as this defines the type of technology the vehicle is equipped with that affects emissions.

For a particular vehicle, the drive cycle over a journey is the key factor that determines the amount of pollutant emitted over a given distance. Key parameters affecting emissions are the acceleration, deceleration, steady speed and idling characteristics of the journey, as well as other factors affecting load on the engine such as road gradient and vehicle weight. However, work has shown that for modelling vehicle emissions for an inventory covering a road network on a national scale, it is sufficient to calculate emissions from emission factors in g/km related to the average speed of the vehicle in the drive cycle (Zachariadis and Samaras, 1997). A similar conclusion was reached in the review of emission modelling methodology carried out by TRL on behalf of DfT (Barlow and Boulter, 2009, see http://assets.dft.gov.uk/publications/road-vehicle-emission-factors-2009/report-2.pdf). Emission factors for average speeds on the road network are then combined with the national road traffic data.

Vehicle and fuel type

Emissions are calculated for vehicles of the following types:

- Petrol cars;
- Diesel cars;
- Petrol Light Goods Vehicles (Gross Vehicle Weight (GVW) ≤ 3.5 tonnes);
- Diesel Light Goods Vehicles (Gross Vehicle Weight (GVW) ≤ 3.5 tonnes);
- Rigid-axle Heavy Goods Vehicles (GVW > 3.5 tonnes);
- Articulated Heavy Goods Vehicles (GVW > 3.5 tonnes);
- Buses and coaches; and
- Motorcycles.

Total emission rates are calculated by multiplying emission factors in g/km with annual vehicle kilometre figures for each of these vehicle types on different types of roads.

Vehicle kilometres by road type

Hot exhaust emission factors are dependent on average vehicle speed and therefore the type of road the vehicle is travelling on. Average emission factors are combined with the number of vehicle kilometres travelled by each type of vehicle on rural roads and higher

speed motorways/dual carriageways and many different types of urban roads with different average speeds and the emission results combined to yield emissions on each of these main road types:

- Urban;
- Rural single carriageway; and
- Motorway/dual carriageway.

DfT estimates annual vehicle kilometres (vkm) for the road network in Great Britain by vehicle type on roads classified as trunk, principal and minor roads in built-up areas (urban) and non-built-up areas (rural) and motorways (DfT, 2012c). DfT provides a consistent time series of vehicle km data by vehicle and road types going back to 1993 for the 2011 inventory, taking into account any revisions to historic data. In particular, during 2012 DfT revised their vehicle km estimates for minor roads over the time series from 2000-2010 as a result of a new benchmarking exercise on the traffic census data collected over these years using more up-to-date information on traffic flows on minor roads. Additional information discussed later was used to provide the breakdown in vkm for cars by fuel type.

Vehicle kilometre data for Northern Ireland by vehicle type and road class were provided by the Department for Regional Development (DRD), Northern Ireland, Road Services (DRDNI, 2011a). These provided a consistent time-series of vehicle km data for all years up to 2010. Data for 2011 was not available for this year's inventory and were derived using change factors provided by DRDNI (2012a). Data for 2010 has been revised slightly upward for artic HGVs and buses and downward for LGVs, however, the changes were within 1%. Motorcycle vehicle km data were not available from the DRDNI and so they were derived based on the ratio of motorcycles registered in Northern Ireland relative to the GB each year. The ratios were then applied to the motorcycle vehicle km activity data for the GB. There has been a downward revision to the motorcycle vehicle km data for Northern Ireland across the time series as updated GB licensing statistics have been used in 2011 inventory. Additional information is provided by DRDNI about the split between cars and LGVs and the petrol/diesel car split for cars and LGVs in the traffic flow based on further interrogation by DRDNI of licensing data (DRDNI, 2012b).

The Northern Ireland data have been combined with the DfT data for Great Britain to produce a time-series of total UK vehicle kilometres by vehicle and road type from 1970 to 2011 as shown in **Table 3-23**.

Table 3-23 UK vehicle km by road vehicles

Billion vkm		1990	1995	2000	2005	2009	2010	2011
Petrol cars	urban	142.2	137.9	135.1	119.9	105.2	99.5	96.7
	rural	141.1	134.1	134.2	127.3	113.4	109.1	105.0
	m-way	49.2	48.4	53.0	48.8	43.4	41.7	39.7
Diesel cars	urban	5.8	17.2	26.1	40.8	52.8	54.1	57.2
	rural	6.1	18.0	28.3	47.6	64.1	65.8	70.0
	m-way	2.8	8.5	14.6	25.1	33.2	33.5	36.6
Petrol LGVs	urban	11.1	7.5	4.2	1.9	1.4	1.3	1.2
	rural	11.4	8.3	5.0	2.3	1.8	1.6	1.5
	m-way	3.9	3.2	2.0	0.9	0.7	0.6	0.6
Diesel LGVs	urban	5.7	10.2	15.5	21.2	22.2	22.6	23.0

Billion vkm		1990	1995	2000	2005	2009	2010	2011
	rural	6.1	11.5	18.8	26.0	29.1	29.5	29.5
	m-way	2.0	4.4	7.4	10.5	11.5	11.4	11.9
Rigid HGVs	urban	4.5	3.7	3.9	4.0	3.3	3.2	3.1
	rural	7.1	6.8	7.2	7.5	6.7	6.6	6.4
	m-way	3.7	3.7	4.2	4.2	4.0	4.1	3.8
Artic HGVs	urban	1.1	1.1	1.1	1.0	0.8	0.8	0.8
	rural	4.3	4.7	5.1	5.3	5.0	5.0	5.0
	m-way	4.7	6.0	7.4	7.9	7.3	7.5	7.5
Buses	urban	2.4	2.9	3.0	3.2	3.0	3.1	2.9
	rural	1.7	1.5	1.7	1.5	1.6	1.6	1.4
	m-way	0.6	0.5	0.5	0.5	0.4	0.5	0.4
M/cycle	urban	3.3	1.9	2.3	2.9	2.7	2.5	2.4
	rural	2.0	1.6	2.0	2.2	2.1	1.8	2.0
	m-way	0.3	0.3	0.4	0.4	0.4	0.4	0.4
Total		**423.4**	**443.9**	**483.0**	**513.0**	**516.1**	**507.9**	**509.0**

Vehicle speeds by road type

Vehicle speed data are used to calculate emission factors from the emission factor-speed relationships available for different pollutants. Average speed data for traffic in a number of different areas were taken from the following main sources: Transport Statistics Great Britain (DfT, 2009b) provided averages of speeds in Central, Inner and Outer London surveyed at different times of day during 1990 to 2008. Speeds data from other DfT's publications such as 'Road Statistics 2006: Traffic, Speeds and Congestion' (DfT, 2007a) and 2008 national road traffic and speed forecasts (DfT, 2008a) were used to define speeds in other urban areas, rural roads and motorways. Where new information is not available, previous NAEI assumptions were maintained or road speed limits used for the vehicles expected to observe these on the type of road concerned. **Table 3-24** shows the speeds used in the previous and 2010 inventory for light duty vehicles, HGVs and buses. DfT confirmed these data were still valid for 2011.

Table 3-24 Average Traffic Speeds in Great Britain

		Lights kph	Heavies kph	Buses kph
URBAN ROADS				
Central London	Major principal roads	16	16	16
	Major trunk roads	24	24	16
	Minor roads	16	16	16
Inner London	Major principal roads	21	21	24
	Major trunk roads	32	32	24
	Minor roads	20	20	20
Outer London	Major principal roads	31	31	32
	Major trunk roads	46	46	32
	Minor roads	29	29	29
	Motorways	108	87	87
Connurbation	Major principal roads	31	31	24
	Major trunk roads	38	37	24
	Minor roads	30	30	20
	Motorways	97	82	82
Urban	Major principal roads	36	36	32
	Major trunk roads	53	52	32
	Minor roads	35	34	29
	Motorways	97	82	82
RURAL ROADS				
Rural single carriageway	Major roads	77	72	71
	Minor roads	61	62	62
Rural dual carriageway		111	90	93
Rural motorway		113	90	95

Vehicle fleet composition: by age, size, technology and fuel type

Vehicle kilometre data based on traffic surveys do not distinguish between the type of fuels the vehicles are being run on (petrol and diesel) nor on their age. Prior to the 2010 inventory, the petrol car/diesel car mix on different road types was defined by the DfT Vehicle Licensing Statistics and data on the relative mileage done by petrol and diesel cars (DfT, 2008b, pers comm). The latter information, as originated from the National Travel Survey (DfT, 2007b), indicated that diesel cars do on average 60% more annual mileage than petrol cars. It was assumed that the additional mileage done by diesel cars is mainly done on motorways and rural roads. On this basis, it was previously assumed that the petrol car/diesel car mix on urban roads was to be indicated by the population mix according to vehicle licensing data (i.e. that there is no preferential use of diesel or petrol cars on urban roads) and the mix on rural and motorways adjusted to give an overall mileage pattern over all roads in the UK that leads to an average 60% higher annual mileage by diesel cars compared with petrol cars.

Since then, the inventory has made use of the Automatic Number Plate Recognition (ANPR) data provided by DfT (2012d, pers comm) for defining the UK's vehicle fleet composition on the road. The ANPR data has been collected annually (since 2007) over 256 sites in the UK on different road types (urban and rural major/minor roads, and motorways) and regions.

Measurements are made at each site on one weekday (8am-2pm and 3pm-9pm) and one half weekend day (either 8am-2pm or 3pm-9pm) each year in June and are currently available for years 2007 to 2011. There are approximately 1.4-1.7 million observations recorded from all the sites each year, and they cover various vehicle and road characteristics such as fuel type, age of vehicle (which can be associated with its Euro standard), engine sizes, vehicle weight and road types.

Following a series of analysis and discussions with officials from DECC, Defra and DfT, it was concluded that the ANPR data should be best used to define the fleet composition on different road types for the whole of Great Britain (GB) while combining DA-country specific vehicle licensing data (hereafter referred as DVLA data) to define regional variation (DfT, 2010a). The ANPR data is used in two aspects to define:

- Petrol and diesel mix in the car fleet on different road types (urban, rural and motorway).
- Variations in age and Euro standard mix on different road types

As the ANPR data are only available between 2007 and 2011, it was necessary to estimate the road-type variations in the fleet for years before the ANPR became available otherwise a step-change would be introduced in the emission time-series. For the petrol/diesel mix of the GB car fleet as a whole, this was done by extrapolating the 2007 ANPR data back to 1990 based on the rate of change in the proportion of diesel vehicles as indicated by the DfT Vehicle Licensing Statistics. The result was then further adjusted by the DVLA data to define the variation of the petrol/diesel mix by the DA regions. The ANPR data confirmed that there is a preferential use of diesel cars on motorways, as was previously assumed in the inventory, but that preferential usage of diesel cars also extended to urban roads as well, although not to the extent as seen on motorways. For Northern Ireland, there were only two years of ANPR data (2010 and 2011) with reasonable number of observations being recorded. However, they did not show consistent trend or major difference in the proportion of diesel cars observed on different road types, and that the proportion was similar to that implied by the licensing data; as a result, it is assumed that there is no preferential use of diesel cars, and the petrol/diesel mix in car km should follow the proportion as indicated by the licensing statistics provided by DRDNI. This leads to the vehicle km data for petrol and diesel cars on different road types in the UK shown in **Table 3-23**.

The age of a vehicle determines the type of emission regulation that applied when it was first registered. These have successively entailed the introduction of tighter emission control technologies, for example three-way catalysts and better fuel injection and engine management systems. **Table 3-25** shows the regulations that have come into force up to 2011 for each vehicle type. The year 2011 saw the introduction of Euro 5 standards for medium and large-sized vans. The date into service is taken to be roughly the mid-point of the Directive's implementation dates for Type-Approval and New Registrations.

Table 3-25 Vehicles types and regulation classes

Vehicle Type	Fuel	Regulation	Approx. date into service in UK
Cars	Petrol	Pre-Euro 1	
		91/441/EEC (Euro 1)	1/7/1992
		94/12/EC (Euro 2)	1/1/1997
		98/69/EC (Euro 3)	1/1/2001
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2010
	Diesel	Pre-Euro 1	
		91/441/EEC (Euro 1)	1/1/1993
		94/12/EC (Euro 2)	1/1/1997
		98/69/EC (Euro 3)	1/1/2001
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2010
LGVs	Petrol	Pre-Euro 1	
		93/59/EEC (Euro 1)	1/7/1994
		96/69/EEC (Euro 2)	1/7/1997
		98/69/EC (Euro 3)	1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2011
	Diesel	Pre-Euro 1	
		93/59/EEC (Euro 1)	1/7/1994
		96/69/EEC (Euro 2)	1/7/1997
		98/69/EC (Euro 3)	1/1/2001 (<1.3t) 1/1/2002 (>1.3t)
		98/69/EC (Euro 4)	1/1/2006
		EC 715/2007 (Euro 5)	1/7/2011
HGVs and buses	Diesel (All types)	Pre-1988	
		88/77/EEC (Pre-Euro I)	1/10/1988
		91/542/EEC (Euro I)	1/10/1993
		91/542/EEC (Euro II)	1/10/1996
		99/96/EC (Euro III)	1/10/2001
		99/96/EC (Euro IV)	1/10/2006
		99/96/EC (Euro V)	1/10/2008
Motorcycles	Petrol	Pre-2000: < 50cc, >50cc (2 st, 4st)	
		97/24/EC: all sizes (Euro 1)	1/1/2000
		2002/51/EC (Euro 2)	1/7/2004
		2002/51/EC (Euro 3)	1/1/2007

In previous years, the inventory was developed using licensing data to define the age mix of the national fleet and data from travel surveys that showed how annual mileage changes with vehicle age. This was used to split the vehicle km figures by age and Euro classification. The new ANPR data provided direct evidence on the age mix of vehicles on the road and how this varied on different road types and thus obviated the need to rely on licensing data and assumptions about changing mileage with age. The information tended to show that the diesel car, LGV and HGV fleet observed on the road was rather newer than inferred from the licensing records and mileage surveys. However, this information was only available for 2007-2011 and it was important to consider how the trends observed in these limited years of ANPR data availability could be rolled back to earlier years. This was done by developing a

pollutant and vehicle specific factor for each road type reflecting the relative difference in the fleet mix on each road type defined by the ANPR data compared with the GB average between 2007 and 2011 and its impact on emissions. This factor is extrapolated to a value of 1 in 1990 because in this year all vehicles meet pre-Euro 1 standard, and hence differences in the age of the fleet on different road types or DA countries have no effect on emissions. This factor is then combined with a DA-specific "driver" derived from trends in licensing data to account for the relative differences in the fleet in each DA country compared with the GB average. An overall year-, vehicle-, road-, DA- and pollutant-specific factor is then applied to GB average emission factors calculated in the fleet model.

It should be noted that the application of the ANPR and DVLA data is dependent on the vehicle, pollutant and region combination. For instance, when calculating fuel consumption and CO_2 emissions, data on the average mpg fuel efficiency of different sizes of lorries from the Road Freight Statistics and the BSOG data for buses take precedence over the ANPR data, and they are continued to be used to define the fuel consumption/ CO_2 emissions for HGVs and buses respectively, without any adjustment to account for variations in the age of the HGV or bus fleets. For other pollutants where the mpg data from Road Freight Statistics are not used in the calculations of HGV emissions, the ANPR data are utilised. The ANPR or DVLA data have not been analysed or applied to the calculation of other pollutant emissions from buses/coaches, as there are likely to be variations in local bus fleets according to local authority measures to address air quality concerns that will not be reflected by licensing information alone, while coaches spend less time in the areas where they are registered. Similarly, neither the ANPR nor DVLA data have been analysed for motorcycles due to lack of data and their relative small contribution to the overall UK fleet.

The DfT/TRL emission factors cover three engine size ranges for cars: <1400cc, 1400-2000cc and >2000cc. The vehicle licensing statistics have shown that there has been a growing trend in the sales of bigger and smaller engine-sized cars in recent years, in particular for diesel cars at the expense of medium-sized cars. The inventory uses the proportion of cars by engine size varying each year from 2000 onwards based on the vehicle licensing data (DfT, 2012e). In addition, the relative mileage done by different size of vehicles was factored into the ratios, this is to take account of the fact that larger cars do more annual mileage than smaller cars (DfT, 2008b).

To utilise the DfT/TRL emission factors, additional investigation had to be made in terms of the vehicle sizes in the fleet as the emission factors cover three different weight classes of LGVs, eight different size classes of rigid HGVs, five different weight classes of artic HGVs, five different weight classes of buses and coaches and seven different engine types (2-stroke and 4-stroke) and size classes of mopeds and motorcycles. Information on the size fractions of these different vehicle types was obtained from vehicle licensing statistics and used to break down the vehicle km data. Some data were not available and assumptions were necessary in the case of buses, coaches and motorcycles.

DfT Road Freight Statistics (DfT, 2011a) provided a time series of vehicle km (2000-2010) travelled by different HGV weight classes based on the Continuing Survey of Road Goods Transport (CSRGT). The data show that there has been a gradual reduction in traffic activity for the rigid HGVs below 17 tonnes, while there has been an increase in traffic activity for rigid HGVs over 17 tonnes over the period 2000 to 2010. For artic HGVs, the dominant group continues to be those over 33 tonnes, and traffic activity from the below 33 tonnes category have been decreasing over time. This information has been used to allocate HGV vehicle km between different weight classes, although further assumption has to be made as the inventory uses a more detailed breakdown of weight classes than those defined in the

Road Freight Statistics. In 2011, the assumptions for artic (34-40t and 40-50t) have been updated for the whole time series based on further information available from DfT's licensing statistic (DfT, 2012e).

Only limited information on the sizes of buses and coaches by weight exists; based on analysis of local bus operator information, it was assumed that 72% of all bus and coach km on urban and rural roads are done by buses, the remaining 28% by coaches, while on motorways all the bus and coach km are actually done by coaches.

Assumptions on the split in vehicle km for buses outside London by vehicle weight class are based on licensing information and correlations between vehicle weight class and number of seats and whether it is single- or double-decker. It is assumed that 31% of buses are <15t and the remaining are 15-18t. For London buses, the split is defined by the fleet composition provided by Transport for London (TfL, 2012).

For motorcycle, the whole time series of vkm for 2-stroke and 4 stroke motorcycles by different engine sizes are based on a detailed review of motorcycle sales, population and lifetime by engine size. It was also assumed that mopeds (<50cc) operate only in urban areas, while the only motorcycles on motorways are the type more than 750cc, 4-stroke. Otherwise, the number of vehicle kilometres driven on each road type was disaggregated by motorcycle type according to the proportions estimated to be in the fleet. Research on the motorcycle fleet indicated that 2-stroke motorcycles are confined to the <150cc class.

Assumptions made about the proportion of failing catalysts in the petrol car fleet.
A sensitive parameter in the emission calculations for petrol cars is the assumption made about the proportion of the fleet with catalyst systems that have failed, for example due to mechanical damage or failure of the lambda sensor. Following discussions with DfT, it is assumed that the failure rate is 5% per annum for all Euro standards and that up to 2008, only 20% of failed catalysts were rectified properly, but those that were rectified were done so within a year of failing. The revisions are based on evidence on fitting of replacement catalysts. According to DfT there is evidence that a high proportion of replacement catalysts are not Type Approved and do not restore the emission performance of the vehicle to its original level (DfT 2009c). This is being addressed through the Regulations Controlling Sale and Installation of Replacement Catalytic Converters and Particle Filters for Light Vehicles for Euro 3 (or above) LDVs after June 2009. Therefore a change in the repair rate is taken into account for Euro 3 and above petrol LDVs from mid-2009 assuming all failed vehicles are rectified properly.

Voluntary measures and retrofits to reduce emissions
The inventory takes account of the early introduction of certain emission standards and additional voluntary measures to reduce emissions from road vehicles in the UK fleet. The Euro 3 emission standards for passenger cars (98/69/EC) came into effect from January 2001 (new registrations). However, some makes of cars sold in the UK already met the Euro 3 standards prior to this (DfT, 2001). Figures from the Society of Motor Manufacturers and Traders suggested that 3.7% of new cars sold in 1998 met Euro 3 standards (SMMT, 1999). Figures were not available for 1999 and 2000, but it was assumed that 5% of new car sales met Euro 3 standards in 1999 increasing to 10% and 100% in 2000 and 2001 respectively.

Prior to 2010 inventory, it was assumed that a proportion of all new petrol cars sold in the UK would meet Euro 4 standards prior to the mandatory date required by the Directive i.e. in year 2006 for new registrations (DfT, 2004). However, this assumption has since been updated with Euro 4 petrol cars only introduced from year 2006 onwards as set by the

Directive. This is in light of the recent study by King's College and Ricardo-AEA (Carslaw et al., 2011) indicating on the basis of ANPR data and manufacturers' information a lower proportion of Euro 4 cars on the road than previously implied by the inventory.

Freight haulage operators have used incentives to upgrade the engines in their HGVs or retrofit them with particle traps. DETR estimated that around 4,000 HGVs and buses were retrofitted with particulate traps in 2000, and this would rise to 14,000 vehicles by the end of 2005 (DETR, 2000). This was accounted for in the inventory for its effects on NO_x, CO and VOC emissions.

Emissions from HGVs and buses in London

The inventory pays particular attention to the unique features of the HGV and bus fleets in London. This is primarily so as to be able to account for measures taken to reduce emissions and improve air quality in London, but the measures can have an indirect effect on greenhouse gas emissions.

The effect of the Low Emission Zone on emissions from HGVs and buses from 2008 is taken into account by using a different Euro standard mix for HGVs within the LEZ area. To be compliant, vehicles must meet Euro III standards or above from 2008, but this is only in respect of PM emissions. With respect to other pollutant emissions, the London fleet of HGVs and buses (except TfL's buses) are assumed to be the same as the national fleet.

The specific features of the fleet of buses operated by Transport for London (TfL) in London were taken into account. Information from TfL on the Euro standard mix of their fleet of buses was used. Based on information from DfT, it is assumed that approximately 78-87% of all bus km in London are done by TfL buses, the remainder being done by non-TfL buses having the composition of the national bus fleet, except from 2008 onwards where the fleet is modified to be compliant with the LEZ.

Fuel quality

In January 2000, European Council Directive 98/70/EC came into effect relating to the quality of petrol and diesel fuels. This introduced tighter standards on a number of fuel properties affecting emissions. The principal changes in UK market fuels were the sulphur content and density of diesel and the sulphur and benzene content of petrol. The volatility of summer blends of petrol was also reduced, affecting evaporative losses. During 2000-2004, virtually all the diesel sold in the UK was of ultra-low sulphur grade (<50 ppmS), even though this low level sulphur content was not required by the Directive until 2005. Similarly, ultra-low sulphur petrol (ULSP) became on-line in filling stations in 2000, with around one-third of sales being of ULSP quality during 2000, the remainder being of the quality specified by the Directive. In 2001-2004, virtually all unleaded petrol sold was of ULSP grade (UKPIA, 2004). These factors and their effect on emissions were taken into account in the inventory. It is assumed that prior to 2000, only buses had made a significant switch to ULSD, as this fuel was not widely available in UK filling stations.

The introduction of road fuels with sulphur content less than 10ppm from January 2009 is taken into account according to Directive 2009/30/EC.

Hot Emission Factors

The emission factors for different pollutants were mostly taken from the database of vehicle emission factors released by DfT/TRL in 2009 (Boulter et al., 2009) or from EMEP/EEA Emissions Inventory Guidebooks.

Greenhouse gases: N_2O and CH_4

The emission factors for N_2O for all vehicle types are based on the recommendation of the Emissions Inventory Guidebook (EEA, 2010) derived from the COPERT 4 methodology "*Computer Programme to Calculate Emissions from Road Transport*". The DfT/TRL review recommended these emission factors continue to be used for the UK inventory.

For N_2O emissions from petrol cars and LGVs, emission factors are provided for different Euro standards and driving conditions (urban, rural, highway) with adjustment factors that take into account the vehicle's accumulated mileage and the fuel sulphur content; both of these tend to increase emission factors. For diesel cars and LGVs, bulk emission factors are provided for different Euro standards and road types, with no fuel and mileage effects. The factors for motorcycles make no distinction between different Euro standards and road types. In the latest version of Emissions Inventory Guidebook (EEA, 2010), the factors for HGVs and buses have been updated and are provided for different Euro standards, weight classes and driving conditions, instead of a constant factor for all Euro standards and road types as published in the previous guidebook (EEA, 2007).

Table 3-31 summarises the N_2O emission factor for all vehicle types and road conditions in mg/km; the factors for petrol cars and LGVs are shown for zero accumulated mileage, but the inventory takes account of the increase in emissions with mileage. For the latest Euro 3 and 4 cars, emission factors in urban areas increase by around 15% over 50,000km, while for rural and motorway conditions, emission factors increase by as much as 38% over this distance, though starting from a smaller base. The age-mileage functions provided by TRL are used to work out the accumulated mileage effects in the calculation of N_2O emission factors. In the 2011 inventory, corrections were made to N_2O emission factors for rigid HGVs 3.5-7.5t and 7.5-12t as they were previously assigned to emission factors for the heavier weight classes in the 2010 inventory. Corrections were also made to N_2O emission factors for coaches in rural and motorway, and London buses.

N_2O emissions were a problem with early generation petrol cars fitted with three-way catalysts, being formed as a by-product on the catalyst surface during the NO_x reduction process. Emission factors have been declining with successive Euro standards since the first generation of catalysts for Euro 1, presumably due to better catalyst formulations as well as reductions in fuel sulphur content.

Road transport is a relatively unimportant emitter of methane, being only produced as a consequence of incomplete combustion, but largely controlled by catalysts on petrol vehicles. Emission factors are based on the speed-emission functions and road type factors from the 2009 DfT/TRL compilation. Full emission factor-speed relationships were available for cars and LGVs, whereas for HGVs, buses and motorcycles only single averaged factors for urban, rural and motorway roads were available.

Table 3-32 summarises the CH_4 emission factor for all vehicle types and road conditions in mg/km.

The uncertainties in the CH_4 and N_2O factors can be expected to be quite large. However, the relative differences between emission factors used for different technologies, Euro standards and fuels are likely to reflect realistic trends.

Emissions of CH_4 and N_2O from consumption of LPG were calculated from vehicle km data and emission factors (expressed as g of pollutant per km) available from DfT/TRL covering all types of light duty vehicles (cars and LGVs). The problem was estimating the kilometres

travelled by LPG vehicles. Consumption of LPG is relatively small in the UK (0.3% of all road fuels) and there are no reliable data on the number or types of vehicles running on LPG as some vehicles have been converted and conversions are not always logged with the vehicle licensing agency. It is estimated that around 0.4% of all light duty vehicles run on LPG in 2011. As information on the type of LPG vehicles travelling in the UK is not available, it has been assumed that all vehicles using LPG are LGVs and this assumption then allows the kilometres travelled by LPG LGVs to be calculated from fuel efficiency factors for vehicles using this fuel taken from DfT/TRL combined with the total LPG consumption given in DUKES. The LPG kilometres were then combined with the g/km emission factors for CH_4 and N_2O provided by TRL/DfT assuming the fleet composition of LPG vehicles in terms of the mix of Euro standards was the same as for diesel LGVs.

Based on this approach, **Table 3-26** shows fleet-averaged emission factors for vehicles using LPG in the UK in 2011 for each main road type.

Table 3-26 Fleet-weighted emission factors for light duty vehicles running on LPG in 2011

g/km	Urban	Rural	Motorway
CH4	0.0307	0.0172	0.0163
N2O	0.0098	0.0037	0.0020

As emissions arise from the unintended combustion of lubricants in the engine, then all exhaust emission factors will include the contribution of lubricants as well the main fuel to the pollutant emissions when the vehicles were tested. Hence, the emissions of CH_4 and N_2O (and other air pollutants) from lubricants are included implicitly in the hot exhaust emissions for each vehicle and fuel type. Treating emissions of these pollutants separately would lead to a double count.

Air pollutants and Indirect GHGs: Regulated pollutants NO_x, CO, NMVOCs

Emission factors for NO_x were revised in the 2010 inventory (Brown et al., 2012) as recent evidence has shown that there is lack of consistency between the trends in the road transport NO_x emissions inventory and trends in ambient roadside concentrations of NO_x (Carslaw et al., 2011). Moreover, the previous emission factors for some vehicle classes do not seem to reflect real-world NOx emissions, especially for more modern diesel vehicles (Euro 3+). NO_x emission factors from the COPERT 4 v8.1 model (which remain the same in COPERT 4 v9.0) are now being used in the inventory to reflect recent evidence on the performance of vehicle NO_x emissions under real-world conditions. The development of the COPERT 4 model is coordinated by the European Environment Agency and is used widely by other Member States to calculate emissions from road transport. The latest version of the COPERT model is available for download from http://www.emisia.com/copert/.

Emission factors from COPERT 4 v9.0 for total hydrocarbons (THC) have been adopted in the 2011 inventory. The COPERT NOx and THC emission factors are represented as equations relating emission factor in g/km to average speed. These baseline emission factors correspond to a fleet of average mileage in the range of 30,000 to 60,000 kilometres. For petrol cars and LGVs, COPERT provides additional correction factors (for NOx and THC) to take account of degradation in emissions with accumulated mileage. The detailed methodology of emission degradation is provided in the 2009 EMEP/EEA Emissions Inventory Guidebook (EEA, 2010). For NO_x, there are separate emission functions available for Euro V HDVs equipped with Selective Catalytic Reduction (SCR) and Exhaust Gas Recirculation (EGR) systems for NO_x control. According to European Automobile

Manufacturers' association (ACEA), around 75% of Euro V HDVs sold in 2008 and 2009 are equipped with SCR systems, and this is recommended to be used if the country has no other information available (it is not expect that the UK situation will vary from this European average).

The TRL/DfT (Boulter et al., 2009) emission factors for CO are continued to be used in the 2011 inventory, and are also represented as equations relating emission factor in g/km to average speed. The TRL/DfT emission factors are provided for an extensive range of vehicle types, sizes and Euro standards and are based on emission test data for in-service vehicles. The factors are presented as a series of emission factor-speed relationships for vehicles normalised to an accumulated mileage of 50,000 kilometres. Scaling factors are provided to take account of degradation in emissions with accumulated mileage – for some vehicle classes, emission factors actually improved with mileage, but most deteriorated. Scaling factors are also provided to take into account the effects of fuel quality since some of the measurements would have been made during times when available fuels were of inferior quality than they are now, particularly in terms of sulphur content. These fuel scaling factors are also applied to the COPERT emission factors.

Table 3-33 to **Table 3-35** summarise the baseline COPERT NO_x and THC emission factors (before any degradation corrections to the petrol LDVs factors and normalised to current fuels) and the TRL/DfT's CO emission factors (normalised to 50,000km accumulated mileage and current fuels) for all vehicle types under typical urban, rural and motorway road conditions in g/km. The factors have been averaged according to the proportion of different vehicle sizes in the UK fleet based on vehicle licensing statistics. Factors for NMVOCs are derived by subtracting the calculated g/km factors for CH_4 from the corresponding THC emission factors.

The speed-emission factor equations were used to calculate emission factor values for each vehicle type and Euro emission standard at each of the average speeds of the road and area types shown in **Table 3-24**. The calculated values were averaged to produce single emission factors for the three main road classes described earlier (urban, rural single carriageway and motorway/dual carriageway), weighted by the estimated vehicle kilometres on each of the detailed road types taken from DfT.

There is an important point to note from these tables of emission factors. The variation in emission factors with average speed differs with different vehicle types, Euro class and technology and the tables shown here are only meant as an illustration of how average emission factors vary across different road types with typical average speeds and Euro classes. Emission factors are especially sensitive to speed at the low urban speed end of the range. The urban emission factors shown in these tables refer to the average urban speed of 44 kph, but at lower, more congested road speeds the emission factors can be much higher and some pollutants show a different trend across the Euro standards at these low speeds. This is especially true for NO_x emission factors for diesel heavy duty vehicles where Euro V vehicles equipped with SCR can show higher factors for NO_x than the same vehicle of a Euro IV class at particularly low speeds reflecting the poor performance of SCR systems under real-world urban cycles. The Euro V factors for NO_x shown in these tables for HGVs and buses are for a higher urban speed and are a weighted average of different factors for vehicles equipped with SCR and EGR technology. For a detailed assessment of urban emissions, the reader is advised to use the original speed-emission factor relationships for different vehicle categories provided by the sources referenced above and derive their own emission factors.

The inventory uses the TRL fuel scaling factors to take into account the prevailing fuel quality in different years. Various other assumptions and adjustments were applied to the emission factors, as follows.

The emission factors used for NMVOCs, NO_x and CO are already adjusted to take account of improvements in fuel quality for conventional petrol and diesel, mainly due to reductions in the fuel sulphur content of refinery fuels. An additional correction was also made to take account of the presence of biofuels blended into conventional fossil fuel. Uptake rates of biofuels were based on the figures from HMRC (2012) and it was assumed that all fuels were consumed as weak (typically 5%) blends with fossil fuel. The effect of biofuel (bioethanol and biodiesel) on exhaust emissions was represented by a set of scaling factors given by Murrells and Li (2008). A combined scaling factor was applied to the emission factors according to both the emission effects of the biofuel and its uptake rates each year. The effects on these pollutants are generally rather small for these weak blends.

Account was taken of some heavy duty vehicles in the fleet being fitted with pollution abatement devices, perhaps to control particulate matter emissions (PM), or that otherwise lead to reductions in NO_x, CO and NMVOC emissions beyond that required by Directives. Emissions from buses were scaled down according to the proportion fitted with oxidation catalysts or diesel particulate filters (DPFs) and the effectiveness of these measures in reducing emissions from the vehicles. The effectiveness of these measures in reducing emissions from a Euro II bus varies for each pollutant and is shown in **Table 3-27**.

Table 3-27 Scale Factors for Emissions from a Euro II Bus Fitted with an Oxidation Catalyst or DPF

		NO_x	CO	NMVOCs
Oxidation catalyst	Urban	0.97	0.20	0.39
	Rural	0.95	0.22	0.55
DPF	Urban	0.90	0.17	0.19
	Rural	0.88	0.19	0.27

These scale factors based on data from LT Buses (1998).

Euro II HGVs equipped with DPFs have their emissions reduced by the amounts shown in **Table 3-28**.

Table 3-28 Scale Factors for Emissions from a Euro II HGV Fitted with a DPF

		NO_x	CO	NMVOCs
DPF	Urban	0.81	0.10	0.12
	Rural	0.85	0.10	0.12

Cold-Start Emissions

Cold start emissions are the excess emissions that occur when a vehicle is started with its engine below its normal operating temperature. The excess emissions occur from petrol and diesel vehicles because of the lower efficiency of the engine and the additional fuel used when it is cold, but more significantly for petrol cars, because the three-way catalyst does not function properly and reduce emissions from the tailpipe until it has reached its normal operating temperature.

Cold start emissions are calculated following the recommendations made by TRL in a review of alternative methodologies carried out on behalf of DfT (Boulter and Latham, 2009). Their main conclusion was that the inventory approach ought to take into account new data and

modelling approaches developed in the ARTEMIS programme and COPERT 4 (EEA, 2007). However, it was also acknowledged that such an update can only be undertaken once the ARTEMIS model and/or COPERT 4 have been finalised and that at the time of their study it was not possible to give definitive emission factors for all vehicle categories.

Boulter and Latham (2009) also stated that it is possible that the incorporation of emission factors from different sources would increase the overall complexity of the UK inventory model, as each set of emission factors relates to a specific methodology. It was therefore necessary to check on progress made on completing the ARTEMIS and COPERT 4 methodologies and assess their complexities and input data requirements for national scale modelling.

The conclusion from this assessment of alternative methodologies was that neither ARTEMIS nor a new COPERT 4 was sufficiently well-developed for national scale modelling and that COPERT 4 referred to in the CORINAIR Emissions Inventory Guidebooks still utilises the approach in COPERT III (EEA, 2000). COPERT III was developed in 2000 and is quite detailed in terms of vehicle classes and uses up-to-date information including scaling factors for more recent Euro standards reflecting the faster warm-up times of catalysts on petrol cars. COPERT III is a trip-based methodology which uses the proportion of distance travelled on each trip with the engine cold and a ratio of cold/hot emission factor. Both of these are dependent on ambient temperature. Different cold/hot emission factor ratios are used for different vehicle types, Euro standards, technologies and pollutants.

Cold start emissions are calculated from the formula:

$E_{cold} = \beta \cdot E_{hot} \cdot (e^{cold}/e^{hot} - 1)$
where

E_{hot} = hot exhaust emissions from the vehicle type
β = fraction of kilometres driven with cold engines
e^{cold}/e^{hot} = ratio of cold to hot emissions for the particular pollutant and vehicle type

The parameters β and e^{cold}/e^{hot} are both dependent on ambient temperature and β is also dependent on driving behaviour in particular the average trip length, as this determines the time available for the engine and catalyst to warm up. The equations relating e^{cold}/e^{hot} to ambient temperature for each pollutant and vehicle type were taken from COPERT III and were used with monthly average temperatures for central England based on historic trends in Met Office data.

The factor β is related to ambient temperature and average trip length by the following equation taken from COPERT III:

$\beta = 0.6474 - 0.02545 \cdot l_{trip} - (0.00974 - 0.000385 \cdot l_{trip}) \cdot t_a$
where

l_{trip} = average trip length
t_a = average temperature

The method is sensitive to the choice of average trip length in the calculation. A review of average trip lengths was made, including those from the National Travel Survey, which highlighted the variability in average trip lengths available (DfT, 2007b). A key issue seems to be what the definition of a trip is according to motorist surveys. The mid-point seems to be

a value of 10 km given for the UK in the CORINAIR Emissions Inventory Guidebook, so this figure was adopted (EEA, 2007).

The COPERT III method provides pollutant-specific reduction factors for β to take account of the effects of Euro 2 to Euro 4 technologies in reducing cold start emissions relative to Euro 1.

This methodology was used to estimate annual UK cold start emissions of NO_x, CO and NMVOCs from petrol and diesel cars and LGVs. Emissions were calculated separately for each Euro standard of petrol cars. Cold start emissions data are not available for heavy-duty vehicles, but these are thought to be negligible (Boulter, 1996).

All the cold start emissions are assumed to apply to urban driving.

Cold start emissions of N_2O were estimated using a method provided by the COPERT 4 methodology for the Emissions Inventory Guidebook (EEA, 2007). The method is simpler in the sense that it uses a mg/km emission factor to be used in combination with the distances travelled with the vehicle not fully warmed up, i.e. under "cold urban" conditions. For petrol cars and LGVs, a correction is made to the cold start factor that takes into account the vehicle's accumulated mileage and the fuel sulphur content, in the same way as for the hot exhaust emission. The cold start factors in mg/km for N_2O emissions from light duty vehicles are shown in **Table 3-29**. There are no cold start factors for HGVs and buses.

Table 3-29 Cold Start Emission Factors for N_2O (in mg/km)

mg/km	Petrol cars	Petrol LGVs	Comment
Pre-Euro 1	10.0	10.0	
Euro 1	34.0	43.4	
Euro 2	23.7	55.0	
Euro 3	11.6	20.9	
Euro 4	6.1	15.6	
Euro 5	6.1	15.6	Assume same as Euro 4

Data for estimating cold start effects on methane emissions are not available and are probably within the range of uncertainty in the hot exhaust emission factors. Cold start effects are mostly an issue during the warm up of three-way catalyst on petrol cars when the catalyst is not at its optimum efficiency in reducing hydrocarbon, NO_x and CO emissions, but without measured data, it would be difficult to estimate the effects on methane emissions. During this warm-up phase, one might expect higher methane emissions to occur, but as the catalyst is less effective in reducing methane emissions when fully warmed up compared with other more reactive hydrocarbons on the catalyst surface, the cold start effect and the excess emissions occurring during the catalyst warm up phase is probably smaller for methane emissions than it is for the NMVOCs. As petrol cars contribute less than 0.5% of all UK methane emissions across the time series, the effect of excluding potential and unquantifiable cold start emissions will be very small.

Evaporative Emission

Evaporative emissions of petrol fuel vapour from the tank and fuel delivery system in vehicles constitute a significant fraction of total NMVOC emissions from road transport. The methodology for estimating evaporative emissions is based on the COPERT 4 simple approach from the Emissions Inventory Guidebook (EEA, 2007). This is the preferred approach to use for national scale modelling of evaporative emissions for the UK inventory,

as concluded from a review by Stewart et al. (2009) and recommendations of a review carried out by TRL under contract to DfT (Latham and Boulter 2009).

There are three different mechanisms by which gasoline fuel evaporates from vehicles:

i) Diurnal Loss
This arises from the increase in the volatility of the fuel and expansion of the vapour in the fuel tank due to the diurnal rise in ambient temperature. Evaporation through "tank breathing" will occur each day for all vehicles with gasoline fuel in the tank, even when stationary.

ii) Hot Soak Loss
This represents evaporation from the fuel delivery system when a hot engine is turned off and the vehicle is stationary. It arises from transfer of heat from the engine and hot exhaust to the fuel system where fuel is no longer flowing. Carburettor float bowls contribute significantly to hot soak losses.

iii) Running Loss
These are evaporative losses that occur while the vehicle is in motion.

These emissions depend to varying degrees on ambient temperatures, volatility of the fuel, the size of vehicle, type of fuel system (carburettor or fuel injection and whether it uses a fuel return system) and whether the vehicle is equipped with a carbon canister for evaporative emission control. Since Euro 1 standards were introduced in the early 1990s, evaporative emissions from petrol cars and vans have been controlled by the fitting of carbon canisters to capture the fuel vapours which are then purged and returned to the engine manifold thus preventing their release to air. Evaporative emissions were particularly high from vehicles using carburettor fuel intake systems and these have been largely replaced by fuel injection systems on more modern vehicles which have further reduced evaporative losses.

COPERT 4 provides a method and emission factors for estimating evaporative emissions for more detailed vehicle categories and technologies than the previous method and also has the benefit of including factors for motorcycles. The vehicle classes are compatible with those available and currently used by the inventory in the calculation of exhaust emissions, although approximations and assumptions have been necessary to further divide vehicles into technology classes according to the type of fuel control systems used on cars (carburettor and fuel return systems) and carbon canisters fitted to motorcycles, given the absence of any statistics or other information available on these technologies relevant to the UK fleet. It has also not been possible to take into account the failure of VOC-control systems because of lack of data on failure rates and emission levels that occur on failure. The COPERT 4 method uses temperature and trip dependent emission factors, and it utilises look-up tables to assign emission factors according to summer/winter climate conditions and fuel vapour pressure.

The application of the method for the UK inventory required the following input data and assumptions.

The number of petrol cars in the small, medium and large engine size range was required and was taken from national licensing statistics. All Euro 1+ vehicles are assumed to be equipped with carbon canister controls. However, the method provides different emission factors for different sizes of canisters. The numbers of vehicles in the UK equipped with different sized canisters is not available, but the Emissions Inventory Guidebook provides a

table that correlates size of carbon canister with Euro emission class. Hence an assignment of the appropriate COPERT 4 evaporative emission factor can be made to Euro class in the UK fleet.

The method also requires additional information on the number of cars with carburettor and/or fuel return systems. Both these systems lead to higher emissions, the latter because fuel vapour being returned to the fuel tank is warm and therefore heats the fuel in the tank. Data are not available in the UK on the number of cars running with either of these systems, but it was assumed that all pre-Euro 1 cars would be with carburettor and that all Euro 1 onward cars would use fuel injection, but with fuel return systems, hence having high emission factors. The latter is a conservative assumption as some modern cars with fuel injection might be using returnless fuel systems and hence have lower emissions, but it was not possible to know this as there is no association with the car's Euro class.

COPERT 4 provides different emission factors for six classes of motorcycles associated with engine cc, whether the engine operated as 2-stroke or 4-stroke and for the largest motorcycles, whether they were or were not equipped with a carbon canister. A review of the motorcycle fleet had been undertaken to yield most of the required information, but it was necessary to make a conservative assumption that no motorcycles are currently fitted with carbon canisters.

Trip information was required to estimate hot soak and running loss evaporative emissions. The information required is the number of trips made per vehicle per day and the proportion of trips finishing with a hot engine. The same trip lengths as used in the calculation of cold start emissions were used.

The COPERT 4 methodology is based on knowledge of fuel vapour pressure (levels most appropriate for the region in the summer and winter seasons) and climatic conditions (ranges of ambient temperatures most applicable to the region in the summer and winter seasons). Based on the information on seasonal fuel volatility received annually from UKPIA (2012), the COPERT 4 emission factors adopted for summer days were those associated with 70 kPa vapour pressure petrol and cooler summer temperature conditions and those adopted for winter days were those associated with 90 kPa vapour pressure petrol and milder winter temperature conditions characteristic of the UK climate.

The seasonal emission factors were applied based on the number of summer and winter days in each month. However as the COPERT 4 emission factors are also classified by fuel vapour pressure, the number of summer and winter days in each month has been defined by whether the fuel sold in that month is either a winter or summer blend or a mixture of both. The information from UKPIA indicates the average vapour pressure of fuels sold in the UK in the summer, winter and also the transitional spring and autumn months. This information allows identification of summer and winter months for the purpose of assigning COPERT 4 evaporative emission factor (winter months have an average vapour pressure of 90 kPa or more and summer months have a vapour pressure of 70 kPa or less). In the transitional months (September, May), the equivalent number of winter and summer days in the month were calculated from the average vapour pressure for the month assuming a winter fuel vapour pressure of 90 kPa and a summer blend vapour pressure of 70 kPa. From this, weighted average evaporative emission factors could be derived for the month.

Further details of the methodology and tables of emission factors are given in the EMEP Emission Inventory Guidebook (EMEP, 2007).

An implied emission factor based on the population, composition of the fleet and trips made in 2011 is shown for petrol cars and motorcycles in **Table 3-30**. The units are in g per vehicle per day.

Table 3-30 Fleet-average emission factor for evaporative emissions of NMVOCs in 2011

g/vehicle.day	2011
Petrol cars	0.75
Motorcycles	1.63

Table 3-31 N_2O Emission Factors for Road Transport (in mg/km)

N_2O(mg/km)	Standard	Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	10.0	6.5	6.5
	Euro 1	21.3	13.8	6.9
	Euro 2	10.7	3.4	1.8
	Euro 3	1.4	0.6	0.5
	Euro 4	1.8	0.6	0.5
	Euro 5	1.8	0.6	0.5
Diesel cars	Pre-Euro 1	0.0	0.0	0.0
	Euro 1	2.0	4.0	4.0
	Euro 2	4.0	6.0	6.0
	Euro 3	9.0	4.0	4.0
	Euro 4	9.0	4.0	4.0
	Euro 5	9.0	4.0	4.0
Petrol LGVs	Pre-Euro 1	10.0	6.5	6.5
	Euro 1	22.0	13.8	6.9
	Euro 2	16.3	9.3	5.8
	Euro 3	10.5	4.6	4.6
	Euro 4	0.8	1.3	1.3
	Euro 5	0.8	1.3	1.3
Diesel LGV	Pre-Euro 1	0.0	0.0	0.0
	Euro 1	2.0	4.0	4.0
	Euro 2	4.0	6.0	6.0
	Euro 3	9.0	4.0	4.0
	Euro 4	9.0	4.0	4.0
	Euro 5	9.0	4.0	4.0
Rigid HGVs	Pre-Euro I	30.0	30.0	30.0
	Euro I	10.4	8.6	6.1
	Euro II	10.0	8.6	5.7
	Euro III	4.9	4.9	3.7
	Euro IV	10.6	12.9	10.6
	Euro V	27.6	37.1	31.3
Artic HGVs	Pre-Euro I	30.0	30.0	30.0
	Euro I	17.6	14.7	10.8
	Euro II	17.6	14.7	9.8
	Euro III	8.8	8.8	6.8
	Euro IV	18.6	22.9	18.8
	Euro V	47.9	65.1	54.5
Buses	Pre-Euro I	30.0	30.0	30.0
	Euro I	11.7	11.2	7.0
	Euro II	11.7	11.2	6.0
	Euro III	5.7	5.7	4.0
	Euro IV	12.4	13.1	11.4

N_2O(mg/km)	Standard	Urban	Rural	Motorway
	Euro V	32.2	35.2	33.6
Mopeds, <50cc, 2st	Pre-Euro 1	1.0		
	Euro 1	1.0		
	Euro 2	1.0		
	Euro 3	1.0		
Motorcycles, >50cc, 2st	Pre-Euro 1	2.0	2.0	
	Euro 1	2.0	2.0	
	Euro 2	2.0	2.0	
	Euro 3	2.0	2.0	
Motorcycles, >50cc, 4st	Pre-Euro 1	2.0	2.0	2.0
	Euro 1	2.0	2.0	2.0
	Euro 2	2.0	2.0	2.0
	Euro 3	2.0	2.0	2.0

Table 3-32 CH_4 Emission Factors for Road Transport (in mg/km)

mg CH4/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	73.0	21.8	57.7
	Euro 1	15.0	5.2	20.9
	Euro 2	15.8	9.6	9.7
	Euro 3	5.0	4.1	7.2
	Euro 4	1.3	1.0	1.8
	Euro 5	1.3	1.0	1.8
Diesel cars	Pre-Euro 1	12.3	10.2	10.0
	Euro 1	6.1	6.3	6.2
	Euro 2	2.9	1.7	1.2
	Euro 3	1.4	1.1	1.1
	Euro 4	1.0	0.8	0.7
	Euro 5	1.0	0.8	0.7
Petrol LGVs	Pre-Euro 1	73.0	21.8	57.7
	Euro 1	15.0	5.2	20.9
	Euro 2	15.8	9.6	9.7
	Euro 3	5.0	4.1	7.2
	Euro 4	1.3	1.0	1.8
	Euro 5	1.3	1.0	1.8
Diesel LGV	Pre-Euro 1	11.8	4.0	22.0
	Euro 1	6.7	1.7	5.8
	Euro 2	2.9	1.7	1.2
	Euro 3	2.2	0.6	1.0
	Euro 4	1.5	0.4	0.7
	Euro 5	1.5	0.4	0.7
Rigid HGVs	Pre-Euro I	185.5	50.2	43.6
	Euro I	85.0	23.0	20.0
	Euro II	54.4	20.0	18.6
	Euro III	47.6	21.4	18.2
	Euro IV	2.6	1.6	1.2
	Euro V	2.3	1.4	1.1
Artic HGVs	Pre-Euro I	381.8	174.5	152.7
	Euro I	175.0	80.0	70.0

mg CH4/km		Urban	Rural	Motorway
	Euro II	112.0	69.6	65.1
	Euro III	98.0	74.4	63.7
	Euro IV	5.3	5.6	4.2
	Euro V	4.7	5.0	3.8
Buses & coaches	Pre-Euro I	381.8	174.5	152.7
	Euro I	175.0	80.0	70.0
	Euro II	113.8	52.0	45.5
	Euro III	103.3	47.2	41.3
	Euro IV	5.3	5.6	4.2
	Euro V	4.7	5.0	3.8
Mopeds, <50cc, 2st	Pre-Euro 1	219.0		
	Euro 1	43.8		
	Euro 2	24.1		
	Euro 3	19.7		
Motorcycles, >50cc, 2st	Pre-Euro 1	150.0	150.0	
	Euro 1	99.0	106.5	
	Euro 2	30.0	31.5	
	Euro 3	12.0	13.5	
Motorcycles, >50cc, 4st	Pre-Euro 1	200.0	200.0	200.0
	Euro 1	127.9	138.6	148.7
	Euro 2	126.7	93.1	107.1
	Euro 3	76.2	32.6	31.8

Table 3-33 NO_x Emission Factors for Road Transport (in g/km), before degradation correction for petrol cars and LGVs[21]

g NO_x (as NO_2 eq)/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	2.11	2.66	3.58
	Euro 1	0.26	0.31	0.59
	Euro 2	0.14	0.16	0.19
	Euro 3	0.07	0.06	0.06
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Diesel cars	Pre-Euro 1	0.57	0.53	0.74
	Euro 1	0.57	0.58	0.74
	Euro 2	0.60	0.56	0.79
	Euro 3	0.69	0.67	0.86
	Euro 4	0.48	0.44	0.72
	Euro 5	0.35	0.31	0.52
Petrol LGVs	Pre-Euro 1	2.82	3.34	3.97
	Euro 1	0.41	0.42	0.61
	Euro 2	0.14	0.14	0.21

[21] The emission factors shown here are illustrative of magnitude and variability with vehicle and road type. The factors for urban roads refer to an average urban speed of 44 kph, but at lower, more congested road speeds the emission factors can be much higher and show a different trend across the Euro standards at these low speeds. For a detailed assessment of urban emissions, the reader is advised to use the original speed-emission factor relationships for different vehicle categories provided by the sources referenced above and derive their own emission factors. The Euro V factors for HDVs are a weighted average of factors vehicles equipped with SCR and EGR for NO_x control.

g NO_x (as NO_2 eq)/km		Urban	Rural	Motorway
	Euro 3	0.09	0.09	0.13
	Euro 4	0.04	0.04	0.06
	Euro 5	0.03	0.03	0.04
Diesel LGV	Pre-Euro 1	1.29	0.81	2.08
	Euro 1	1.05	1.01	1.50
	Euro 2	1.05	1.01	1.50
	Euro 3	0.88	0.85	1.26
	Euro 4	0.71	0.68	1.02
	Euro 5	0.51	0.49	0.73
Rigid HGVs	Pre-Euro I	8.65	7.89	7.91
	Euro I	5.92	5.45	5.51
	Euro II	6.40	5.77	5.76
	Euro III	5.01	4.45	4.42
	Euro IV	3.47	3.19	2.86
	Euro V	2.77	1.34	0.81
Artic HGVs	Pre-Euro I	13.95	11.17	10.07
	Euro I	9.79	7.87	7.13
	Euro II	10.42	8.36	7.59
	Euro III	8.35	6.72	6.14
	Euro IV	5.74	4.81	3.59
	Euro V	3.83	1.94	1.27
Buses & coaches	Pre-Euro I	10.84	9.31	8.64
	Euro I	7.26	6.00	6.42
	Euro II	7.85	6.47	7.00
	Euro III	6.14	4.66	5.33
	Euro IV	4.21	3.35	3.85
	Euro V	3.35	2.16	1.91
Mopeds, <50cc, 2st	Pre-Euro 1	0.03		
	Euro 1	0.03		
	Euro 2	0.01		
	Euro 3	0.01		
Motorcycles, >50cc, 2st	Pre-Euro 1	0.03	0.04	
	Euro 1	0.04	0.05	
	Euro 2	0.05	0.06	
	Euro 3	0.02	0.04	
Motorcycles, >50cc, 4st	Pre-Euro 1	0.22	0.45	0.57
	Euro 1	0.23	0.44	0.57
	Euro 2	0.13	0.31	0.66
	Euro 3	0.07	0.16	0.34

Table 3-34 CO Emission Factors for Road Transport (in g/km) normalised to 50,000 km accumulated mileage (where applicable)

g CO/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	9.77	6.85	5.53
	Euro 1	2.42	1.64	3.13
	Euro 2	0.53	0.69	1.82
	Euro 3	0.23	0.62	1.58
	Euro 4	0.42	0.71	1.56
	Euro 5	0.34	0.58	1.29
Diesel cars	Pre-Euro 1	0.58	0.43	0.36
	Euro 1	0.32	0.22	0.18
	Euro 2	0.19	0.12	0.08
	Euro 3	0.06	0.04	0.02
	Euro 4	0.05	0.03	0.02
	Euro 5	0.04	0.02	0.01
Petrol LGVs	Pre-Euro 1	11.69	8.17	6.69
	Euro 1	3.10	3.25	4.81
	Euro 2	0.10	1.15	3.12
	Euro 3	0.41	0.77	2.22
	Euro 4	0.41	0.77	2.22
	Euro 5	0.33	0.63	1.82
Diesel LGV	Pre-Euro 1	0.71	0.77	0.95
	Euro 1	0.55	0.46	0.43
	Euro 2	0.59	0.62	0.76
	Euro 3	0.17	0.13	0.12
	Euro 4	0.14	0.10	0.09
	Euro 5	0.11	0.08	0.08
Rigid HGVs	Pre-Euro I	2.14	1.96	2.06
	Euro I	1.38	1.30	1.37
	Euro II	1.17	1.12	1.18
	Euro III	1.04	0.96	0.98
	Euro IV	0.57	0.50	0.55
	Euro V	0.08	0.07	0.07
Artic HGVs	Pre-Euro I	2.49	2.26	2.39
	Euro I	2.17	1.98	2.10
	Euro II	1.80	1.69	1.83
	Euro III	1.91	1.74	1.86
	Euro IV	0.34	0.31	0.34
	Euro V	0.13	0.12	0.13
Buses & coaches	Pre-Euro I	2.72	1.89	1.50
	Euro I	1.68	1.11	1.24
	Euro II	1.33	0.87	1.13
	Euro III	1.46	0.92	1.22
	Euro IV	0.13	0.08	0.09
	Euro V	0.13	0.09	0.09
Mopeds, <50cc, 2st	Pre-Euro 1	13.80		
	Euro 1	5.60		
	Euro 2	1.30		
	Euro 3	1.30		
Motorcycles, >50cc, 2st	Pre-Euro 1	16.08	23.67	

g CO/km		Urban	Rural	Motorway
	Euro 1	10.61	15.62	
	Euro 2	8.39	12.35	
	Euro 3	4.63	6.82	
Motorcycles, >50cc, 4st	Pre-Euro 1	16.59	22.01	25.84
	Euro 1	10.08	17.56	15.74
	Euro 2	5.27	8.98	9.51
	Euro 3	2.91	4.96	5.25

Table 3-35 THC Emission Factors for Road Transport (in g/km), before degradation correction for petrol cars and LGVs. NMVOC emission factors are derived by subtracting methane factors from the THC factors

g HC/km		Urban	Rural	Motorway
Petrol cars	Pre-Euro 1	1.299	0.818	0.711
	Euro 1	0.154	0.115	0.119
	Euro 2	0.061	0.045	0.044
	Euro 3	0.014	0.017	0.033
	Euro 4	0.012	0.014	0.019
	Euro 5	0.012	0.014	0.019
Diesel cars	Pre-Euro 1	0.122	0.078	0.055
	Euro 1	0.052	0.032	0.029
	Euro 2	0.045	0.029	0.019
	Euro 3	0.020	0.012	0.010
	Euro 4	0.009	0.006	0.006
	Euro 5	0.009	0.006	0.006
Petrol LGVs	Pre-Euro 1	1.403	0.475	0.884
	Euro 1	0.175	0.082	0.099
	Euro 2	0.042	0.020	0.024
	Euro 3	0.025	0.011	0.014
	Euro 4	0.011	0.005	0.006
	Euro 5	0.011	0.005	0.006
Diesel LGV	Pre-Euro 1	0.120	0.101	0.118
	Euro 1	0.120	0.101	0.118
	Euro 2	0.120	0.101	0.118
	Euro 3	0.074	0.063	0.073
	Euro 4	0.028	0.023	0.027
	Euro 5	0.028	0.023	0.027
Rigid HGVs	Pre-Euro I	0.825	0.538	0.371
	Euro I	0.422	0.294	0.220
	Euro II	0.282	0.193	0.142
	Euro III	0.260	0.176	0.128
	Euro IV	0.037	0.029	0.027
	Euro V	0.023	0.018	0.015

g HC/km		Urban	Rural	Motorway
Artic HGVs	Pre-Euro I	0.683	0.463	0.341
	Euro I	0.635	0.436	0.323
	Euro II	0.418	0.284	0.208
	Euro III	0.386	0.263	0.193
	Euro IV	0.059	0.044	0.039
	Euro V	0.036	0.027	0.023
Buses & coaches	Pre-Euro I	1.099	0.812	0.311
	Euro I	0.488	0.358	0.316
	Euro II	0.334	0.248	0.209
	Euro III	0.310	0.237	0.207
	Euro IV	0.047	0.038	0.033
	Euro V	0.028	0.024	0.021
Mopeds, <50cc, 2st	Pre-Euro 1	13.910		
	Euro 1	2.730		
	Euro 2	1.560		
	Euro 3	1.200		
Motorcycles, >50cc, 2st	Pre-Euro 1	7.521	7.442	
	Euro 1	2.362	2.863	
	Euro 2	1.254	1.521	
	Euro 3	0.784	0.948	
Motorcycles, >50cc, 4st	Pre-Euro 1	1.595	1.302	1.726
	Euro 1	0.896	0.793	0.807
	Euro 2	0.394	0.432	0.577
	Euro 3	0.246	0.270	0.362

Fuel consumption data for 1A3b were obtained from national statistics for all overseas territories and crown dependencies. Fleet composition data were available for some territories and used within the calculations. Detailed fleet data from the UK GHGI were used to break down the fuel consumption data in order to apply UK-specific emission factors.

3.2.11.2.5 Railways (1A3c)

The following is a summary of the methods used to develop the inventory for railways and recalculations and methodological changes made in the 2013 submission of the inventory:

Summary of Methodology

A Tier 2 methodology is used for calculating emissions from diesel trains as well coal-fired heritage trains.

Summary of emission factors

Factors for N_2O are from the 2009 EMEP / EEA Emissions Inventory Guidebook. UK specific emission factors in g/vehicle (train) km are used for other gases. These are taken from the Department for Transport's Rail Emissions Model (REM) for different rail engine classes based on factors provided by WS Atkins Rail. Data from UKPIA on carbon and sulphur content of gas oil are used.

Summary of activity data

Gas oil consumption data from Office of Rail Regulation for passenger and freight trains for 2005-2009 combined with trends in train km to estimate consumption for other years. Train km data from the REM are used to provide the breakdown between train class.

Summary of recalculations and methodology changes

The recalculations for rail primarily stem from the incorporation of information for the first time from the UK Department for Transport's detailed strategic Rail Emissions Model (REM). This contains detailed information on the vehicle kilometres undertaken by each class of passenger train as well as new emission factors (DfT, 2012a). Estimates for the freight sector remain largely unchanged, with a minor revision to infrastructure activity.

The recalculations were undertaken as part of the inventory improvement programme aimed at addressing comments from expert reviewers of the greenhouse gas inventory in 2011 to "*improve the completeness and transparency of reporting category-specific emissions for railway*s". The inventory for this sector now has greater traceability through direct links to the UK's Rail Emissions Model at the Department for Transport under development for national transport policy.

The effect of these changes on the calculations of rail emissions in 2010 compared with the previous inventory is summarised as follows:

- Total rail fuel consumption and CO_2 emissions are unchanged, but there is a significant redistribution of fuel from use by Intercity trains to regional passenger trains.

- There is a large decrease (44%) in overall 2010 CH_4 emissions; this is due to a very large decrease in CH_4 factors for regional trains to bring them more in line with the Guidebook.

- There is a very large decrease (98%) in overall N_2O emissions. This was due to adoption of the factors for rail engines in the Emissions Inventory Guidebook, the previously used factors being unrealistically high.

Details of methodology

The UK inventory reports emissions from both stationary and mobile sources.

Railways (stationary)
The inventory source "*railways (stationary)*" comprises emissions from the combustion of burning oil, fuel oil and natural gas by the railway sector. The natural gas emission derives from generation plant used for the London Underground. These stationary emissions are reported in **Section 3.2.12**. These emissions are based on fuel consumption data from DECC (2012).

Railways (mobile)
Most of the electricity used by the railways for electric traction is supplied from the public distribution system, so the emissions arising from its generation are reported under 1A1a Public Electricity. In this sector, emissions are reported from the consumption of gas oil used to power diesel trains and from the consumption of coal used to power steam trains.

Coal consumption data has been obtained from DUKES. Estimates have been made across the time-series from 1990-2011 and are believed to be due to consumption by heritage trains. For the air pollutants, US EPA emission factors for hand-stoked coal-fired boilers are used to estimate emissions from coal-fired steam trains.

The UK inventory reports emissions from trains that run on gas oil in three categories: freight, intercity and regional. These are reported under NFR code 1A3c *Railways*. Emission estimates are based on vehicle / train kilometres travelled and UK-specific emission factors in grams per vehicle / train kilometre.

Gas oil consumption by passenger trains was obtained from the Office of Rail Regulation's (ORR's) National Rail Trends Yearbook (NRTY) for the years 2005 to 2009. No data was available for 2010 or 2011 or prior to 2005 and therefore fuel consumption for these years was estimated on the basis of the trend in train kilometres provided by the ORR[22].

Gas oil consumption by freight trains was also obtained from ORR's NRTY for 2005-2009. As with the passenger train estimates, no data from ORR was available for 2010 or 2011 or prior to 2005 and therefore fuel consumption for these years were estimated on the basis of the trend in train tonne kilometres.

In 2011, the estimated fuel consumed by both passenger and freight rail showed an increase in comparison to 2009 as a consequence of increased train kilometres travelled.

Carbon dioxide, sulphur dioxide and nitrous oxide emissions are calculated using fuel-based emission factors and the total fuel consumed as provided in the National Rail Trends Yearbook and interpolations/extrapolations. The N_2O emission factor has been substantially revised in the 2011 inventory and this is now based on the 2009 EMEP / EEA Guidebook.
Emissions of CO, NMVOCs, NO_x and methane are based on the vehicle / train kilometre estimates and emission factors for different train types. The fuel consumption is distributed according to:

- For passenger trains: Vehicle train kilometre and emission factor data taken for different train classes from DfT's REM and extrapolations for 2010 and 2011;
- For freight trains: Train kilometre data taken from the NRTY and extrapolations to 2010 and 2011, with an assumed mix of locomotives and fuel consumption factors for different types of locomotive.

[22] http://dataportal.orr.gov.uk/displayreport/report/html/df2ac230-682c-4041-9b29-8f4d4d732af7

The emission factors shown in **Table 3-36** are aggregate implied factors for trains running on gas oil in 2011, so that all factors are reported on the common basis of fuel consumption.

The passenger train emission factors have been modified in line with the REM; no revisions have been made to any of the freight emission factors which are provided in terms of g/km. However, for freight trains this leads to a change on a kt/Mt basis due to small changes to the fuel consumption estimates.

The emission factor for SO_2 has decreased from 1.44 kt/ Mt fuel in 2010 to 0.76 kt/ Mt fuel in 2011 in line with data from UKPIA (2012) showing a reduction in the sulphur content of gas oil.

Table 3-36 Railway Emission Factors for 2011 (kt/Mt fuel)

	C[1]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2
Freight	870	0.2	0.024	109.9	12.4	6.23	0.76
Intercity	870	0.12	0.024	38.9	8.4	3.03	0.76
Regional	870	0.1	0.024	47.2	8.4	2.58	0.76

1 Emission factors expressed as ktonnes carbon per Mtonne fuel

3.2.11.2.6 Navigation (1A3d)

The following is a summary of the methods used to develop the inventory for navigation and recalculations and methodological changes made in the 2013 submission of the inventory. A description of the methodology used for fishing reported under 1A4ciii and military shipping reported under 1A5b are also included in this section.

Summary of Methodology

A Tier 2/3 methodology is used for calculating emissions from domestic coastal navigation, inland waterways, fishing, naval shipping and international marine bunkers using vessel, engine and fuel-specific, and in some case, movement specific emission factors and activity data.

Summary of emission factors

For domestic coastal shipping, fishing, military and international marine bunker emissions, the emission factors are taken from the EMEP/EEA Emissions Inventory Guidebook and country specific factors used for CO_2 and SO_2. These are supplemented by factors for indirect greenhouse gases from the study by Entec (2010), originating from Lloyds Register Engineering Services and a study by IVL for different vessel, fuel and movement types. For inland waterway vessels, engine and fuel-specific emission factors were taken from the EMEP/EEA Emissions Inventory Guidebook.

Summary of activity data

Detailed shipping vessel movement data provided by Entec (2010) were used for 2007. Port movement data from DfT Maritime Statistics were used to estimate trends for other years. For inland waterways, bottom-up estimates from population and hours of use of vessels in 2008/2009 were used and various proxy statistics used as activity drivers for different groups of vessel types to estimate fuel consumption in other years. UK fishing statistics were used to estimate fuel consumption from UK fishing activities and fuel consumption data provided by the MoD were used for naval shipping. A reconciliation with total gas oil and fuel oil consumption statistics given in DUKES was used to estimate fuel consumption by UK international maritime bunkers.

Summary of recalculations and methodology changes
Following comments made by reviewers during the In-Country Review of the UK's Greenhouse Gas Inventory in 2012, emissions from UK fishing activities in waters outside the Entec study area and emissions from vessel movements between the UK and overseas territories have been included for the first time. This led to a revision in the fuel consumption and emissions attributed to international marine bunkers in order to retain the overall marine fuel balance with figures in DUKES.

Details of methodology

The method for estimating domestic coastal shipping is centred around a procedure developed by Entec (now AMEC) under contract to Defra for calculating fuel consumption and emissions from shipping activities around UK waters. The method uses a bottom-up procedure based on detailed shipping movement data for different vessel types, fuels and journeys (Entec, 2010). The approach represents a Tier 3 method for estimating emissions from domestic water-borne navigation in the IPCC Guidelines for national inventories.

Further Tier 3 approaches are used to estimate emissions from inland waterways, and other emissions away from UK waters which the UK is responsible, including fishing activities and vessel movements between the UK and overseas territories. The latter were included for the first time in this version of the inventory.

The balance in total marine fuel consumption is used to define emissions from international marine bunkers following a Tier 2 approach.

Prior to the 2009 inventory (reported in 2011), emission estimates for coastal and international marine were based on total deliveries of fuel oil, marine diesel oil and gas oil to marine bunkers and for national navigation given in national energy statistics (DUKES, 2012). This led to very erratic time series trends in fuel consumption and emissions which bear little resemblance to other activity statistics associated with shipping such as port movement data. The total fuel delivery statistics given in DUKES (marine bunker plus national navigation) are believed to be an accurate representation of the total amount of fuel made available for marine consumption, but there is more uncertainty in the ultimate distribution and use of the fuels for domestic and international shipping consumption.

The shipping inventory developed by Entec (2010) provides estimates of shipping for journeys that can be classified as domestic, for journeys departing from or arriving at UK ports on international journeys and for journeys passing through UK shipping waters, but not stopping at UK ports, nor using UK fuels. The detailed study covered movements in only one year, 2007, but Entec used proxy data to backcast movements and fuel consumption to 1990 and forward cast to 2009. A methodology consistent with that described by Entec (2010) has been used to forward cast to 2011.

According to emission reporting guidelines, emissions from domestic coastal shipping are included in national totals, whereas emissions for international marine are not, but are reported as a Memo item for information. To meet the overall requirements for reporting emissions from shipping to CLRTAP, the method adopted for the UK inventory uses the results from Entec for coastal shipping based on movement data for domestic journeys while at the same time using an estimation for international marine that retains consistency with total marine fuels data reported in DUKES after also accounting for other uses of marine fuels for purposes where the UK is responsible for emissions. Emissions from naval shipping

continue to be based on fuel consumption data reported by the MoD. Estimates of emissions from inland waterways and fishing are reported separately.
Following comments made by reviewers during the In-Country Review of the UK's Greenhouse Gas Inventory in 2012, emissions from UK fishing activities in waters outside the Entec study area and emissions from vessel movements between the UK and overseas territories have been included for the first time. This leads to a revision in the method used for international marine bunker emissions in order to maintain the overall marine fuel balance with DUKES. The overall approach can be summarised as follows:

- Fuel consumption and emissions for domestic journeys are taken from the Entec study based on detailed movement data for 2007. Entec provided an uplift to their bottom-up estimates to take account of missing vessel movements
- Fuel consumption and emissions for fishing vessels in UK waters are taken from the Entec study and reported separately under 1A4ciii
- Estimates for domestic coastal shipping fuel consumption and emissions backcast to 1990 and forecast to 2011 are used
- Fuel consumption and emissions are calculated separately for naval shipping from data provided by the MoD
- Fuel consumption and emissions are calculated separately for inland waterways from estimates of vessel population and activities
- Fuel consumption and emissions are calculated separately for fishing which takes place in non-UK waters by UK vessels
- Fuel consumption and emissions are calculated separately for shipping movements between the UK and Overseas Territories
- A reconciliation with fuels data in DUKES is made whereby the ***difference*** between the sum of the currently reported fuel deliveries for marine bunkers and national navigation in DUKES and the sum of the fuel consumption estimate for domestic coastal shipping taken from Entec, and the fuel consumption estimates for naval shipping, the UK's inland waterways, fishing outside UK waters and shipping movements between the Overseas Territories, is assigned to international shipping.

Details in the approach for the elements of these parts of the inventory for navigation are given in the following sections, including the methodologies for inland waterways, naval shipping, fishing outside UK waters and shipping movements between the UK and Overseas Territories. Further details of the bottom-up methodology for estimating fuel consumption and emissions based on shipping vessel movements are given in the Entec (2010) report.

Estimation for Domestic Coastal Shipping Emissions in 2007 (1A3dii)
Entec developed a gridded emissions inventory from ship movements within waters surrounding the UK including the North Sea, English Channel, Irish Sea and North East Atlantic. The study area was 200 nautical miles from the UK coastline and fuel consumption and emissions were resolved to a 5x5km grid and included emissions from vessels cruising at sea and manoeuvring and at berth in port.

The Entec inventory was based on individual vessel movements and characteristics data provided by Lloyd's Marine Intelligence Unit (LMIU) for the year 2007 supplemented by Automatic Identification System (AIS) data transmitted by vessels to shore with information about a ship's position and course. A major part of the Entec study was to consider vessel movements not captured in the LMIU database. These were known to include small vessels and those with multiple callings to the same port each day, such as cross-channel passenger ferries. To assess this, Entec carried out a detailed comparison between the LMIU data and DfT port statistics. The DfT port statistics (DfT, 2008c) are derived from primary LMIU data

in combination with estimates from MDS-Transmodal for frequent sailings missing from the LMIU database. The DfT port data are reported as annual totals by port and ship type in Maritime Statistics and refer to movement of all sea-going vessels >100 Gross Tonnage (GT) involved in the movement of goods or passengers. In this comparison, special consideration was given to movements involving small vessels <500 tonnes, fishing vessels and movements from and to the same port. Missing from both data sources are movements by tugs, dredgers, research vessels and other vessels employed within the limit of the port or estuary as well as small pleasure craft.

The comparisons showed the extent by which the LMIU data underestimated port arrivals for each port most likely from missing vessels <300 GT with multiple callings each day. A more detailed analysis highlighted the particular movements underestimated in each port by the LMIU database and from this an estimate could be made as to the missing fuel consumption and emissions which needed to be incorporated into the final gridded inventory. The main outcome of the analysis was a series of scaling factors by which fuel consumption derived for the LMIU database (as described below) were uplifted for each vessel category involved in domestic and international movements.

The LMIU movement data included vessel type and speed. The vessel types were grouped into the following eight vessel categories:

- Bulk carrier
- Container ship
- General cargo
- Passenger
- Ro-Ro cargo
- Tanker
- Fishing
- Other

This categorisation marks the differences between engine and vessel operation between different vessel types and along with the vessel size gives an indication of the likely fuel used, whether fuel oil or marine diesel oil/gas oil (marine distillate).

Fuel consumption and emissions were calculated for each of these vessel categories for different operations. Vessel speeds were combined with distance travelled to determine the time spent at sea by each vessel. Entec undertook a detailed analysis of port callings where a significant proportion of emissions occur. The analysis considered time-in-mode for manoeuvring, hotelling in ports and loading and unloading operations.

The LMIU data were analysed to determine engine characteristics that influence fuel consumption and emissions for each vessel type. This included engine size, engine type and any installed abatement technology, together with fuel type, engine power and engine speed for both the main ship engine and auxiliary engines.

Fuel types were assigned depending on whether the vessel is travelling within or outside a Sulphur Emission Control Area (SECA). The area defined as a SECA was as defined in the Sulphur Content of Marine Fuels Directive (SCMFD) which came into force in July 2005 setting a maximum permissible sulphur content of marine fuels of 1.5%. Around the UK coast, the SECA came into effect in August 2007 covering the North Sea and English Channel and sulphur limits also apply for passenger vessels between EU ports from August 2006. For the purposes of the inventory, it was assumed that the sulphur limit applied to all

vessels in the SECA for the full 2007 calendar year and on this basis all shipping fuel used within a SECA was either marine diesel oil (MDO) or marine gas oil (MGO).
For vessel movements outside the SECA, vessels were assumed to be using either residual fuel oil (with a higher sulphur content) or MGO or MDO. Entec made the allocation according to vessel type and whether the engine was the main ship engine or auxiliary engine. Details are given in Entec (2010).

Entec calculated fuel consumption and emissions from g/kWh emission factors appropriate for the engine type and fuel type for operations "at sea" cruising, "at berth" when stationary in port and for "manoeuvring" while entering and leaving port. The 2007 emission factors and formulae used for calculating emissions are given in the Entec report. As well as the time spent cruising, in berth and manoeuvring, the formulae used the installed engine power and average load factor for the main ship engine and auxiliary engines.

The emission factors used by Entec come from amendments to an earlier set of emission factors compiled by Entec during a study for the European Commission (Entec, 2002, 2005). These largely originate from Lloyds Register Engineering Services and a study by IVL.

The Entec study considered only fuel consumption and CO_2 emissions and emissions of NO_x, SO_2, PM and NMVOCs, but did not cover other greenhouse gases, CH_4 and N_2O. For NO_x, the factors took into account limits on emissions from engines installed on ships constructed or converted after 1 January 2000, as required to meet the NO_x Technical Code of the MARPOL agreement. As the age of the engine is identified in the LMIU dataset, an average factor for engines in 2007 could be determined. Emission factors for SO_2 depend on the sulphur content of the fuel. Entec made the following assumptions for each fuel based on current limits and data from IVL:

Table 3-37 Assumed sulphur content of fuel for 2007

	Sulphur content of fuel (2007)
Marine gas oil	0.2%
Marine diesel oil	1.5%
Residual fuel oil	2.7%

Factors for NMVOCs are unchanged from those in Entec (2005).

For pollutants not covered in the Entec (2010) study, including CH_4 and N_2O, emission factors in units g/kg fuel were taken from the EMEP/EEA guidebook.

The detailed Tier 3 approach used by Entec is able to distinguish fuel consumption and emissions between domestic movements from one UK port to another and UK international movements between a UK port and a port overseas. This enables the emissions to be allocated to the NFR category 1A3dii Domestic Water-borne Navigation separate from 1A3di International Water-borne Navigation (International bunkers), according to NFR Source Categories:

Table 3-38 Navigation Source Category and description

Category	Description
1A3di International Water-borne Navigation (International bunkers)	Emissions from fuels used by vessels of all flags that are engaged in international water-borne navigation. The international navigation may take place at sea, on inland lakes and waterways and in coastal waters. Includes emissions from journeys that depart in one country and arrive in a different country.
1A3dii Domestic Water-borne Navigation	Emissions from fuels used by vessels of all flags that depart and arrive in the same country

Emissions from domestic navigation (1A3dii) are included in the national totals, emissions from international navigation (1A3di) are not included in national totals, but are reported as a Memo item for information.

It should be noted that the gridded inventory developed by Entec also included fuel consumption and emissions from passing vessels not calling at UK ports. These emissions from transit vessels are not included in the UK inventory. The Entec inventory also excluded emissions and fuel consumption from military vessel movements which are not captured in the LMIU and DfT database. Naval shipping emissions are reported separately using fuel consumption data supplied by the MoD. The Entec study did not cover small tugs and service craft used in estuaries, private leisure craft and vessels used in UK rivers, lakes and canals. These were captured in the estimates for inland waterways described below.

Fishing was one of the vessel categories treated by Entec, so this enables emissions from fishing vessels to be reported separately under the NFR category 1A4ciii. Entec only covered emissions from fishing activities occurring within the UK waters study area extending 200 nautical miles from the UK coast. Emissions from UK fishing activities outside this area are described later.

Estimating the Time Series in Domestic Coastal Shipping Emissions from 1990

The LMIU data used by Entec only covered vessel movements during the 2007 calendar year. Applying the same approach to other years required considerable additional time and resources, so an alternative approach was used based on proxy data to develop a consistent time series in emissions back to 1990 and forward to 2011 from the 2007 base year emissions. The variables that were considered were:

- Trends in vessel movements over time affected by changes in the number of vessels and their size.
- Trends in fuel type in use over time reflecting the era before the introduction of SECAs which would have permitted higher sulphur content fuel to be used
- Changes in emission factors.

The key consideration was the trend in vessel movements over time. For this, DfT's annual published Maritime Statistics were used as proxies for activity rate changes which were taken to be indicators of fuel consumed. A range of time-series trends back to 1990 from the DfT statistics are available and appropriate data were assigned to different vessel categories,

differentiating between international and domestic movements. Details are given in the Entec (2010) report, but in brief:

- All ports traffic data based on tonnes cargo for domestic and international movements was assigned as an indicator for the bulk carrier, general cargo and tanker vessel categories. Trends were available from 1990-2011.
- All ports main unitised statistics reported as number of units for domestic and international movements was assigned as an indicator for the container ship and Ro-Ro cargo vessel categories. Trends were available from 1990-2011
- International and domestic sea passenger movements reported as number of passengers was assigned to the passenger vessel category

A time-series of tonnes fish landed in the UK provided in UK Sea Fisheries Statistics by the Marine Management Organisation was used for the domestic fishing vessels category (MMO, 2011).

The Entec (2010) report shows the trends in each of the relevant statistics relative to the 2007 base year level. Figure 13.1 in that report shows that before 2007, all statistics were showing a growth in the level of activity from 1990 with the exception of three. These were trends in ports traffic (tonnes cargo) for domestic movements, international sea passenger numbers and fish landings which showed declining activity. However, in the period between 2007 and 2009, almost all statistics showed a decreasing level of activity. Between 2009 and 2011 there was little change in these statistics. The small changes resulted in an overall decreasing trend in fuel consumption from 2010 to 2011.

It was assumed that 2007 heralded the introduction of marine gas oil and marine diesel oil consumption by vessels that had previously used residual fuel oil in the SECA around UK coasts. Thus in years between 1990-2006, all vessels except fishing and those in the 'other' category were assumed to be using fuel oil for their main engine. It was also assumed that passenger vessels outside the SECA started to use MDO in 2007 in order to comply with the SCMF Directive having previously been using fuel oil. However, other vessels outside the SECA were assumed to continue to be using fuel oil across the 1990-2011 time-series. Overall, this implies a large decrease in fuel oil consumption accompanied by a large increase in MDO/MGO consumption in 2007. Information from UKPIA and DECC shows that fuel oil is still used for marine consumption.

As far as changes in emission factors are concerned, the main consideration was in changes in factors for NO_x and SO_2 over time. The issue for NO_x was the proportion of pre- and post-2000 engines installed on ships since engines installed after January 2000 must comply with the NO_x Technical Code. For each year, an estimated engine replacement rate was used to estimate the proportion of pre- and post-2000 engines in the fleet and from this a weighted NO_x emission factor was derived. It was assumed that emission factors were constant in years before 2000.

SO_2 factors are based on the sulphur content of each type of fuel. Prior to 2007, such figures were based on assumptions from CONCAWE and Entec (2005). As described in the revised MARPOL Annex VI, the maximum permitted sulphur content of marine fuels for vessels operating in a SECA became 1.5% in 2007, reducing to 1% from 1 July 2010. The average sulphur content of Marine Diesel Oil (MDO) and Marine Gas Oil (MGO) for domestic coastal shipping assumed by Entec was around 1% in 2007, i.e. below the 2010 limit for a SECA. Therefore the overall sulphur content and SO_2 factors for consumption of gas oil (the average

of MDO and MGO) was held constant from 2007 onwards at 1% and assumed to apply to all domestic vessels operating around the UK.

Fishing vessels were assumed by Entec to be using MGO with a sulphur content of 0.2% in 2007 and 0.1% from 2008 onwards.

Information from UKPIA and DECC shows that fuel oil is still used for marine consumption. UKPIA indicate that two types of bunker fuel oil are supplied for consumption with different sulphur contents for use inside and outside SECAs. For domestic consumption of fuel oil, it is assumed that fuel oil meeting the SECA limits is used which according to UKPIA had a sulphur content of 1.3% in 2008 falling to 0.9% in 2011. The higher sulphur content fuel oil is assumed to be used for international shipping only. According to UKPIA, these range from 2.2% in 2008 to 1.4% sulphur in 2011. These are below the global MARPOL limit on sulphur content for marine fuels outside SECAs of 4.5% (up to January 2012).

For all other pollutants, emission factors remained constant over the time-series.

Emissions from military shipping (1A5b)

Emissions from military shipping are reported separately under NFR code 1A5b. Emissions are calculated using a time-series of naval fuel consumption data (naval diesel and marine gas oil) provided directly by the Sustainable Development and Continuity Division of the Defence Fuels Group of the MoD (MoD, 2012). Data are provided on a financial year basis so adjustments were made to derive figures on a calendar year basis.

Implied emission factors derived for international shipping vessels running on marine distillate (MGO and MDO) from the Entec (2010) study were assumed to apply for military shipping vessels.

Emissions from Inland Waterways (1A3dii)

The IPCC Guidelines specify that category 1A3d Waterborne Navigation should include not only fuel used for marine coastal shipping, but also for passenger vessels, ferries, recreational watercraft, other inland watercraft, and other gasoline-fuelled watercraft. These small vessels were not included in the Entec study.

The Guidelines recommend national energy statistics be used to calculate emissions, but if these are unavailable then emissions should be estimated from surveys of fuel suppliers, vessel movement data or equipment (engine) counts and passenger and cargo tonnage counts. The UK has no national fuel consumption statistics on the amount of fuel used by inland waterways in DUKES, but they are included in the overall marine fuel statistics. It was therefore necessary to use a Tier 3, bottom-up approach based on estimates of population and usage of different types of inland waterway vessels to estimate their emissions. In the UK, all emissions from inland waterways are included in domestic totals whereas in some other countries, vessels on inland waterways could be classed as international since they pass between countries.

The methodology applied to derive emissions from the inland waterways sector for the 2011 inventory uses the 2007 and 2009 EMEP/EEA Emissions Inventory Guidebooks (EMEP/EEA, 2007, 2009a). The inland waterways class is divided into four categories and sub-categories:

- Sailing Boats with auxiliary engines;
- Motorboats / Workboats (e.g. dredgers, canal, service, tourist, river boats);
    - recreational craft operating on inland waterways;
    - recreational craft operating on coastal waterways;
    - workboats;
- Personal watercraft i.e. jet ski; and
- Inland goods carrying vessels.

Details of the approach used are given in the report by Walker et al (2011). A bottom-up approach was used based on estimates of the population and usage of different types of craft and the amounts of different types of fuels consumed. Estimates of both population and usage were made for the baseline year of 2008 for each type of vessel used on canals, rivers and lakes and small commercial, service and recreational craft operating in estuaries / occasionally going to sea. For this, data were collected from stakeholders, including the British Waterways, DfT, Environment Agency, Maritime and Coastguard Agency (MCGA), and Waterways Ireland.

The methodology used to estimate the total amount of each fuel consumed by the inland waterways sector follows that described in the EMEP/EEA Emissions inventory guidebook (EMEP, 2009b) where emissions from individual vessel types are calculated using the following equation:

$$E = \sum_i N \times HRS \times HP \times LF \times EFi$$

where:

E = mass of emissions of pollutant i or fuel consumed during inventory period,
N = source population (units),
HRS = annual hours of use,
HP = average rated horsepower,
LF = typical load factor,
EFi = average emissions of pollutant i or fuel consumed per unit of use (e.g. g/kWh).

The method requires:

- a categorisation of the types of vessels and the fuel that they use (petrol, DERV or gas oil);
- numbers for each type of vessel, together with the number of hours that each type of vessel is used;
- data on the average rated engine power for each type of vessel, and the fraction of this (the load factor) that is used on average to propel the boat;
- g/kWh fuel consumption factors and fuel-based emission factors.

A key assumption made is that privately owned vessels with diesel engines used for recreational purposes use DERV while only commercial and service craft and canal boats use gas oil (Walker et al., 2011). Some smaller vessels also run on petrol engines. As a result, around 90 kt of DERV and 90 kt of petrol previously assigned to the road transport sector for 2009 in the 2009 inventory are now allocated to inland waterways.

Walker at al. (2011) and Murrells et al. (2011) draw attention to the potential overlap between the larger vessels using the inland waterways and the smaller vessels in the shipping sectors (namely tugboats and chartered and commercial fishing vessels), and the judgement and assumptions made to try to avoid such an overlap.

As it was only possible to estimate population and activities for one year (2008), proxy statistics were used to estimate activities for different groups of vessels for other years in the time series 1990 – 2011:

- Private leisure craft – ONS Social Trends 41: Expenditure, Table 1, Volume of household expenditure on "Recreation and culture"; http://www.ons.gov.uk/ons/rel/social-trends-rd/social-trends/social-trends-41/index.html. No data were available for this dataset after 2009, therefore a second dataset was used to estimate the activity in 2010-11: OECD.Stat data: http://stats.oecd.org/Index.aspx?QueryId=9189# - 'Final consumption expenditure of households, UK, 1990-2011', P31CP090: Recreation and culture);.
- Commercial passenger/tourist craft – Visit England, Visitor Attraction Trends in England 2011, Full Report, http://www.visitengland.org/insight-statistics/major-tourism-surveys/attractions/Annual Survey/, Slides 10&12: "Total England Attractions"
- Service craft (tugs etc.) – DfT Maritime Statistics, Port traffic trends. Table PORT0104 - All UK port freight traffic, foreign, coastwise and one-port by direction; http://www.dft.gov.uk/statistics/releases/port-freight-statistics-2010-final-figures/; and
- Freight – DfT Waterborne Freight in the United Kingdom, Table DWF0101: Waterborne transport within the United Kingdom, 1990 – 2010; Goods lifted - UK inland waters traffic - Non-seagoing traffic – Internal http://www.dft.gov.uk/statistics/releases/waterborne-freight-in-the-uk-2010

One of these four proxy data sets was assigned to each of the detailed vessel types covered in the inventory and used to define the trends in their fuel consumption from the 2008 base year estimate.

Table 3-39 shows the trend in fuel consumption by inland waterways from 1990-2011 developed for the inventory this year. More detail regarding the vessels and their fuel type can be found in the report by Walker et al., 2011. The fuel-based emission factors used for all inland waterway vessels were taken from the EMEP Emissions Inventory Guidebook and implied factors for 2011 are presented later. The factors for SO_2 from vessels using gas oil took into account the introduction of the much tighter limits on the sulphur content of gas oil for use by inland waterway vessels, the limit reduced to 10ppm from January 2011.

Table 3-39 Fuel consumption for inland waterways derived from inventory method

Year	Fuel Consumption (kt)					
	Gas Oil		Diesel		Petrol	
	Motorboats / workboats	Inland goods-carrying vessels	Sailing boats with auxiliary engines	Motorboats / workboats	Motorboats / workboats	Personal watercraft
1990	86.2	3.82	0.59	27.6	22.0	11.2
1991	86.5	3.44	0.62	28.8	22.6	11.7
1992	86.9	3.76	0.68	31.5	24.1	12.8
1993	88.4	4.07	0.74	34.3	25.5	13.9
1994	92.8	4.52	0.80	37.0	27.0	15.0
1995	94.3	4.20	0.85	39.8	28.5	16.1
1996	94.9	3.63	0.91	42.5	29.9	17.2

Year	Fuel Consumption (kt)					
	Gas Oil		Diesel		Petrol	
	Motorboats / workboats	Inland goods-carrying vessels	Sailing boats with auxiliary engines	Motorboats / workboats	Motorboats / workboats	Personal watercraft
1997	95.2	3.06	0.97	45.3	31.1	18.3
1998	95.8	2.74	1.03	48.0	32.2	19.4
1999	95.5	2.74	1.09	50.7	33.6	20.5
2000	96.1	2.74	1.15	53.5	34.8	21.6
2001	94.5	2.71	1.21	56.2	35.9	22.8
2002	96.0	2.52	1.30	60.4	38.7	24.4
2003	96.4	2.02	1.39	64.6	41.0	26.1
2004	98.8	1.65	1.48	68.8	43.2	27.8
2005	100.2	2.16	1.57	72.9	45.2	29.5
2006	101.1	2.26	1.66	77.1	47.6	31.2
2007	101.7	2.14	1.75	81.3	49.9	32.9
2008	100.3	2.35	1.84	85.5	52.2	34.6
2009	94.6	2.08	1.93	89.6	54.8	36.3
2010	97.0	1.87	1.98	92.2	56.3	37.3
2011	99.0	1.87	2.00	93.2	57.2	37.7

Emissions from Deep Sea Fishing in Sea Territories outside UK Waters (1A4ciii)

The Entec study covers only domestic emissions from fishing vessels that stay within UK waters (covering a sea area up to 200 nautical miles from the UK coast), leaving from and returning to UK ports. In response to comments from reviewers during the In-Country review of the UK's Greenhouse Gas Inventory in 2012, emissions have been estimated for the first time from commercial fishing activities occurring in waters outside the Entec study area. These emissions should be included in the UK national totals. .

A Tier 2 approach was used to estimate emissions from deep sea trawlers heading out of the UK waters, fishing and then returning to the UK.

Approach

The Marine Management Organisation (MMO) produces a report annually on the UK fishing industry[23] entitled "*The UK Fishing Industry 2011: Landings*"[24]. This is classed as a National Statistics Publication. This report gives the tonnes of fish landing into the UK and abroad by UK vessels by **area of capture**. The areas of capture are listed in terms of the ICES[25] sea area classification system. The sea areas covered by Entec are broadly the ICES areas IV,

[23] The MMO is an executive non-departmental public body (NDPB) incorporating the work of the Marine and Fisheries Agency (MFA) and marine-related powers and specific functions previously associated with DECC and the Department for Transport (DfT)

[24] http://www.marinemanagement.org.uk/fisheries/statistics/documents/ukseafish/2011/landings.pdf

[25] ICES is the International Council for the Exploration of the Sea. See for example http://www.fao.org/docrep/009/a0210e/a0210e12.jpg

V, VI and VII. The approach considered activities outside these areas. According to the MMO reports, the other areas where the UK actively fishes are listed below:

- Barents Sea/Murman Coast (I)
- Norwegian Coast (IIa)
- Bear Island & Spitzbergen (IIb)
- Bay of Biscay (VIII)
- East Coast of Greenland (XIV)
- North Azores (XII)
- North Azores (XII)

The MMO reports give tonnes fish landed in the UK from each of these areas from 1994-2011 (see for example, Table 8 in the 2011 MMO Landings report).

The approach involved calculating the fuel used by the fleet to reach and return from these "non-UK" sea areas and the fuel consumed whilst fishing in the areas.

To calculate the fuel used to reach and return from these non-UK ICES sea areas it is necessary to know:

- The number of vessel trips to non-UK ICES areas
- The distance from a UK port to a point in the ICES sea area
- The average vessel speed in order to estimate the time taken to reach the sea area
- The typical engine power of the types of vessels used

i) Number of vessel trips

According to the MMO Landings report (Table 8), the fish catches in the non-UK ICES areas are mainly of Pelagic fish such as mackerel and herring (Table 6). These are also mainly caught by the largest vessels, over 24m (Table 10).

A publication by Borges et al[26] on Dutch commercial fishing operations by pelagic trawlers indicated that a small number of very large-sized trawlers (factory trawlers) catch on average **155 tonnes** pelagic fish per vessel per trip based on data for 2005. These are vessels that are over 100m in length with an engine size close to 6,000kW making them similar in size to a bulk carrier ship.

The MMO Landings data for 2011 indicates that 39,500 tonnes fish were caught in the non-UK ICES areas in 2011. Assuming the UK vessels have the same trawling capacity as the Dutch fleet, then this would require **255 vessel trips** per year in 2011.

Although a very rough estimate, this is consistent with information on a Greenpeace website which states that there are 47 pelagic fishing vessels in the UK. If 255 vessel trips are made per year, this would imply each vessel does around 5-6 trips per year.

The Borges et al study stated that the Netherlands has some of the largest fishing vessels in the world. If the UK vessels are generally smaller then they will require more than the 255 trips to the non-UK ICES areas estimated above to make the total catch reported. However

[26] L Borges et al, "What do pelagic freezer-trawlers discard?", ICES Journal of Marine Science, 65: 605–611(2008), http://icesjms.oxfordjournals.org/content/65/4/605.full.pdf

this will be offset by the fact that their engine sizes and hence fuel consumption rates would be lower.

According to Table 3 in the MMO Structure and Activity report, the average engine size of the >24m fleet of vessels in the UK is 1,206 kW which is considerably less than the engine size of the factory trawlers in the Dutch fleet. The largest vessels in the UK fleet are in Scotland (142 vessels >24m, with an average engine size of 1,350 kW). It is possible that very large vessels make up a sub-set of these figures.

For the purpose of these estimates, 255 vessel round-trips was assumed to the non-UK ICES areas in 2011 in conjunction with an assumed engine power for these vessels of 5,800kW. Fish landings for these non-UK ICES areas in other years from the MMO reports were used to calculate number of round-trips in other years.

ii) Distances covered to/from the non-UK ICES sea areas

The MMO information was used to split the tonnes fish landings from the non-UK ICES areas between each area in each year. The tables in the MMO Landing reports indicate that the major areas of capture by UK fishing vessels in the non-UK ICES areas are the north Norwegian coast and 'other areas'. The MMO reports do not specify what 'other areas' refer to, but Chart 18 in the MMO Landings report indicates that Spain and Morocco are major areas outside UK waters receiving landings of pelagic fish from UK vessels. It was therefore assumed that the landings to the UK from 'other areas' are from off the coast of Morocco which is known to be an important fishing area.

Detailed landings data to accompany Chart 17 in the MMO Landings report indicate that 81% of landings of pelagic fish are to major ports in Scotland (Peterhead, Lerwick and Fraserburgh) with 11% to major ports in the south-west of England (mainly Plymouth, Newlyn and Brixham) and the rest to other ports.

It was assumed that all 11% of the landings to the south-west of England were captured in the 'other areas' (designated as Morocco). Peterhead and Lerwick were assumed to take the remaining percent of the landings captured from Morocco and all the landings captured off the coast of Norway and the other minor areas. The Peterhead/Lerwick split was taken to be 65%/35% for all the areas of capture based on MMO data.

This information on landings was used to split the total number of vessel trips from the UK (calculated above) to each of the non-UK ICES sea areas between the "representative" UK ports of Peterhead, Lerwick and Plymouth.

To calculate trip distances, certain central positions were allocated to each area of capture. Distances from the relevant UK port to these positions are shown below:

Table 3-40 Approximate distances to points in each sea area in km

	Peterhead	Lerwick	Plymouth
Barents Sea/Murman Coast (I)	1923	1730	
Norwegian Coast (IIa)	1000	750	
Bear Island & Spitzbergen (IIb)	2600	2300	
Bay of Biscay (VIII)	2000	1875	660
East Coast of Greenland	1800	1700	

	Peterhead	Lerwick	Plymouth
(XIV)			
North Azores (XII)	3000	3000	
Other Areas [(a)]	2900	2900	1700

Using the return port-sea area distances and the number of return trips made, split between each combination of UK port-to-sea area, the total distances travelled per year by all UK fishing trips to the non-UK ICES areas were calculated for each year.

iii) Average vessel speed

An average cruise speed of 25 kph was used for the fishing vessels travelling between the UK port and area of fish capture. This is taken from the EMEP Inventory Guidebook section on marine navigation.

Using this speed with the trip distances calculated above, the total time taken to travel the distances calculated above was derived for each year.

iv) Rated engine power

A rated engine power of 5,800 kW was used for all vessels, consistent with the calculation of number of vessel trips above.

A weighted average engine load factor of 0.46 was used. This was based on an assumption that the vessel would be operating under different loads for different parts of a day. The assumptions were: 5 hrs/day at 80% load, 11 hrs day at 50% load, 8 hrs/day at 20% load.

Fuel consumption

A specific fuel consumption factor of 203 g/kWh was used to calculate total fuel consumption by UK vessels travelling to and returning from the non-UK ICES sea area in conjunction with rated engine power, load factor and total travel time. The fuel consumption factor was taken from Table 3-4 in the EMEP/EEA Emissions Inventory Guidebook 2009 for a medium- and high-speed diesel engine using MDO/MGO.

The fuel used whilst actively fishing in the non-UK areas was calculated by assuming each vessel spends 4 days actively fishing once it has reached its sea area. This was used in conjunction with the same engine power, load information and fuel consumption factor as above to calculate total fuel consumption for all UK vessels whilst actively fishing in these sea areas.

Note that using other information in the MMO reports on total fishing effort in combination with the vessel trip information and landings used here implies that the average time spent fishing is around 3-4 days, consistent with this assumption.

The total fuel consumption for fishing by UK vessels in non-UK ICES areas is the sum of the total fuel consumed during the fishing activity and the total fuel consumed travelling to and from the area of capture.

All the fuel used for deep sea fishing in non-UK waters is assumed to be gas oil sourced in the UK. The emission factors are those used by Entec for fishing vessels in UK waters

supplemented by factors from the EMEP/EEA emissions inventory guidebook (2009) for marine engines.

Emissions from Vessel Movements Between the UK and Overseas Territories (1A3dii)

In response to comments from expert reviewers during the In-Country review of the UK's Greenhouse Gas Inventory in 2012, emissions have been estimated for the first time for vessel movements between the UK and Overseas Territories. These were not included in the Entec study, but need to be included in the UK national totals.

Approach

There are no published data on the number and types of voyages between the UK and overseas territories (OTs). However, officials at the UK Department for Transport were able to interrogate their ports database which forms the basis of the less detailed information published in DfT's Maritime Statistics. This included information on freight shipping movements and passenger vessel movements. Additional information on passenger vessel movements were gathered from individual OT port authorities.

For freight shipping, the DfT were able to provide the number of trips made between a UK port and an OT port by each unique vessel recorded. The information provided the type of vessel and the departure and arrival port. Figures were provided for all years between 2000 and 2011.

The information on the type of vessel was used to define:

- The average cruise speed of the vessel
- The average main engine power (in kW), and
- The specific fuel consumption factor (g/kWh)

This information was taken from the EMEP Emissions Inventory Guidebook 2009[27].

Distances for each voyage were taken from http://www.portworld.com/map/ . This has a tool to calculate route distance by specifying the departure and arrival ports.

Using the distance, average speed, engine power and fuel consumption factor it was possible to calculate the amount of fuel consumed for every voyage made. The estimates were summed for all voyages between the UK and each OT and separately for both for the UK inward and UK outward journeys. For example, the total fuel consumed by all movements from the UK to Gibraltar and from Gibraltar to the UK were estimated separately.

DfT were unable to provide the detailed port data for years before 2000. The individual OT port authorities also did not have this information. The trends in fuel consumption calculated by Entec for all UK international shipping from 1990 to 2000 (based on less detailed UK port statistics) were used to define the trend in fuel consumption between the UK and OTs over these years.

For passenger vessels, the information held by OT port authorities indicated the only movements were by cruise ships (i.e. not ferries). Detailed movement data were held by the port authority of Gibraltar listing all voyages departing to or arriving from the UK back to 2003[28]. The DfT also held information on the number of UK port arrivals by cruise ships from

[27] http://www.eea.europa.eu/publications/emep-eea-emission-inventory-guidebook-2009
[28] http://www.gibraltarport.com/cruise/schedules

the OTs, but only between 1999 and 2004. This is unpublished information and was provided via direct communication with DfT officials.

Information held by the other OTs indicated that only Bermuda had any cruise ship sailings with the UK logged – one voyage in 2010[29]. The data held by DfT showed the majority of sailings were from Gibraltar and the data were consistent with the information provided by the Gibraltar port authority. However, the DfT data also showed a total of 8 arrivals from Bermuda and 3 arrivals from the Falkland Islands between 1999 and 2004.

This information was combined to show the total number of cruise ship movements between the UK and OTs from 1999 to 2011.

The same source of information as described above was used to define the distances travelled, cruise speed, engine power and fuel consumption factor to calculate total fuel consumption by cruise ships between the UK and each OT. The information for passenger ships was taken from the EMEP Guidebook.

No cruise ship information was available before 1999 from either DfT or the individual OT port authorities. Trends in the total number of passengers on cruises beginning or ending at UK ports between 1990 and 1999 published in DfT's Maritime Statistics (from Table 3.1(a) UK international short sea passenger movements, by port and port area: 1950 – 2009) were used to define the trend in fuel consumption by cruise ships between the UK and OTs over these years.

The total fuel consumed by vessels moving between the UK and each OT was calculated as the sum of all fuel consumed by freight and passenger vessels. This was calculated separately for movements from the UK to each OT and from each OT to the UK.

All fuel used for voyages between the UK and OTs is assumed to be fuel oil. The emission factors used are average factors implied by Entec for all vessels involved in international voyages (see below) supplemented by factors from the EMEP/EEA emissions inventory guidebook (2009) for marine engines.

Estimation of International Shipping Emissions from 1990 (1A3di)

Emissions from international marine bunkers are calculated, but reported as a Memo item and not included in the UK totals.

The study by Entec provided a time-series in fuel consumption and emissions from vessels involved in international movements, i.e. those arriving at UK ports from overseas and those leaving UK ports to voyage overseas. However, when adding the estimates of fuel consumption from international movements to fuel consumed by domestic movements (UK port-to-UK port), the sum is different to the total fuel supplied to international marine bunkers and consumed by national navigation in DUKES. This is illustrated in
Table 3-41 which shows the total fuel consumed by domestic and international vessel movements in 2007 according to the Entec methodology compared with the total consumption statistics (national navigation plus marine bunkers) in DUKES for 2007 for fuel oil and gas oil. Note that DUKES makes no separation between marine diesel oil and marine

29 http://www.gov.bm/portal/server.pt/gateway/PTARGS_0_2_998_282_551_43/http;/ptpublisher.gov.bm;7087/publishedcontent/publish/ministry_of_tourism_and_transport/marine_and_ports/dept___marine_and_ports___shipping_news/2010_cruiseship_schedule_3.pdf

gas oil, so the figures here and in the inventory for gas oil refer to the combined amounts for both these types of fuel.

Table 3-41 Total consumption of marine fuels for domestic and international shipping

Mt fuel	Entec	DUKES
Gas oil	4.34	1.57
Fuel oil	1.00	2.04

Note: Data calculated by the Entec method compared and with figures for national navigation and marine bunkers in DUKES for 2007. The DUKES figure for gas oil has consumption by military vessels are excluded

The totals differ markedly. One reason for that is the Entec "international" category includes fuel consumed by vessels arriving at UK ports that purchased their fuel overseas and so would not be included in the DUKES marine bunkers supply. However, in reporting emissions from international shipping movements as a Memo item, the UK is only responsible for emissions from fuel supplied by the UK's bunker fuels market.

Another issue is the international bunker fuels market itself and how the figures in DUKES for marine bunkers relate to actual consumption by international shipping movements starting in the UK. International fuel bunkering may be affected by variations in international marine fuel prices such that it is conceivable that fuel tankering occurs to a greater or lesser extent each year. This may explain why the trend in total marine fuel consumption implied by DUKES since 1990 is more erratic than trends in shipping movements implied by port statistics.

All these factors can lead to potential differences in the total domestic plus international fuel consumption calculated from a method based on vessel movements from fuel statistics in DUKES. Moreover, DECC acknowledged that there is uncertainty with refineries who submit data to DUKES as to where the fuel ultimately gets used, i.e. whether for domestic shipping activities or for international marine fuel bunkers. So not only could the total fuel consumed be different, but these uncertainties could allocate the incorrect amounts of the DUKES marine fuels to domestic (national navigation) and international (marine bunkers) consumption.

The key point is that for emission reporting under IPCC guidelines, the UK is only responsible for emissions from the fuel it supplies, whatever it is used for, but an accurate estimate is required of the amount of fuel used for domestic shipping consumption because emissions arising from this are accounted for in the UK inventory totals. Therefore, to retain overall consistency with national energy statistics and the requirements of inventory reporting under IPCC Guidelines it was decided at a meeting with stakeholders (Defra, DECC, DfT and Entec) in July 2010 to adopt an approach for the inventory whereby the figures for domestic coastal shipping would be taken directly from the Entec study (described above), but the figures for international shipping would be based on the residual fuel consumption. This residual is the difference between the total fuel deliveries statistic in DUKES and the sum of the Entec figure for domestic coastal shipping plus other fuel used for domestic marine purposes sourced in the UK and included in the national totals. These include fuel used for military shipping, inland waterways, deep sea fishing in non-UK waters and fuel used to power vessels on trips from the UK to OTs, but not on the reverse trip.

Discussions with the DUKES team during a study on the allocation of gas oil across sectors (Murrells et al., 2011) revealed that it is likely that gas oil supplied for inland waterway

vessels by marinas and filling points along rivers is included in the DUKES figures for national navigation.

Thus for fuel consumption across the time series:

International shipping fuel consumption = (total DUKES fuel consumption – Entec domestic shipping fuel consumption – naval fuel consumption – inland waterways fuel consumption – fishing vessels outside UK waters fuel consumption – shipping vessels travelling from the UK to overseas territories fuel consumption)

This implies that the total marine fuel consumption by all marine activities covered in the inventory is considered a "closed" system, in other words, the sum of consumption across all the different marine activities (international shipping, domestic coastal shipping, fishing, naval and inland waterways, voyages to overseas territories, fishing outside UK waters) is consistent with the total amount of gas oil and fuel oil used for consumption as given in DUKES for marine bunkers and national navigation. The approach also implies a different domestic/international split to that implied by DUKES. The proportion of fuel consumption (hence emissions) allocated to domestic shipping is considerably smaller than that implied in DUKES as can be seen in Table 3-42. This shows consumption of marine fuels by domestic and international shipping calculated by the inventory approach on the basis of Entec figures for domestic coastal movements and inventory estimates of inland waterway, fishing in non-UK waters and voyages from UK to OTs activities compared with figures for national navigation (domestic) and marine bunkers (international) in DUKES for 2007. The DUKES figure for gas oil (international) has consumption by military vessels excluded. This table differs from the corresponding table in last year's (2010) inventory report because fuel used for fishing in non-UK waters and voyages from UK to OTs are included in domestic consumption.

Table 3-42 Consumption of marine fuels by domestic and international shipping

Mt fuel		NAEI	DUKES
Gas oil	Domestic	0.534	0.942
	International	1.035	0.627
	Total	1.569	1.569
	% domestic	34%	60%
Fuel oil	Domestic	0.122	0.569
	International	1.918	1.471
	Total	2.040	2.040
	% domestic	6%	28%

The inclusion of fuel used for deep sea fishing in non-UK waters and fuel used for voyages from the UK to OTs in the inventory increased the domestic shipping fuel proportion compared with last year's (2010) inventory, but the table still shows how the inventory implies a smaller proportion of fuel is used for domestic activities (as defined for inventory reporting) than is implied by DUKES.

Following this revised approach, emissions for international shipping (1A3di) were calculated by multiplying the residual fuel consumption calculated above with an implied emission factor for international vessel movements. The implied emission factors were derived from the Entec study by dividing the Entec emission estimates for international vessel movement by

their associated fuel consumption for each fuel type. This effectively means the inventory does capture the types of vessels, engines, speeds and activities used for international movements in Entec's inventory even though the overall movements, fuel consumption and hence emissions are different. The same factors were used for voyages between the UK and OTs (see above).

This approach was used to estimate international shipping fuel consumption and emissions for all years back to 1990.

Process following for changes to shipping inventory and reasons behind deviation from DUKES

DUKES derive marine fuel delivery statistics from the information reported monthly to DECC's oil data reporting system. This delivery information is sourced from the accounting departments of refineries. Up to 2010, the inventory team had noted erratic behaviour in the time-series trends for domestic and marine bunkers reported in DUKES which could not be explained. The inventory team had received many enquiries as to this erratic behaviour in the inventory resulting from use of these data from parts of UK government including the marine divisions of the UK Department for Transport who could not reconcile these trends with their own port movement and other statistics. In 2009, the UK's Department for Environment (Defra) commissioned Entec to undertake a detailed bottom-up estimate of air quality pollutant emissions from shipping based on detailed shipping movement data. This highlighted inconsistencies in the split between fuel consumed for international shipping and national navigation calculated in this study with the figures in DUKES. This led to a series of meetings to resolve this discrepancy and suggest a way forward for the inventory.

The initial meeting in March 2009 involved officials from DECC, Defra, DfT, the UK Petroleum Industry Association (UKPIA), Entec and the inventory team. Minutes of the meeting were recorded. It became apparent that the UK Petroleum Industry Association (UKPIA) and the DECC DUKES team did not have confidence in the way responders to the returns had decided to make the allocation for marine bunkers and national navigation, but there was confidence in the total marine fuels made available for consumption. This was expressed in a series of communications to the inventory team after the initial meeting. UKPIA supported the idea that a split based on a bottom-up, vessel movements basis was a better option and the DUKES team at DECC did not object to this proposal.

The UK's inventory team withheld any changes to the methodology until full agreement had been reached across all Parties. Further meetings involving the same Parties were held in 2010 following further developments of the Entec work. A final meeting was held in July 2010 at which a new method for the inventory based on the Entec studies was proposed for domestic shipping, with the balance of marine fuels (from the total given in DUKES) assigned to international bunkers. Minutes of this meeting were recorded and presentations and related material circulated to all Parties. This included a full analysis and explanation of the impacts to the inventory of making the methodology change. Partial agreement in principle was reached at the meeting to use the proposed method for later confirmation. This was recorded in the Minutes and full agreement was later agreed in an email from DECC circulated to Defra, DfT and the inventory team on 11th October 2010. The new method was then adopted for the 2009 version of the inventory published in early 2011 and was described in the UK's 2011 National Inventory Report methodology annex.

The inventory team has regular contact with the DUKES team who are regularly reviewing their data collection systems. The DUKES team need to consider any potential changes to their reporting in future in the context of their wider oil reporting system used.

Consistency with marine fuels data submitted to IEA/EUROSTAT
In response to feedback from the Expert Review Team, the inventory agency has confirmed with the UK national energy statistics team at DECC that the UK allocations of marine bunker fuels reported within DUKES are consistent with the data submitted to EUROSTAT and the IEA across the full time-series. Note, however, that the UK inventory memo item estimates for international shipping deviate from the reported DUKES (and IEA/EUROSTAT) data due to reallocation of some of the bunker fuels to military shipping based on data from the Defence Fuels Group of the MoD; these emissions are included in national inventory estimates and not in the Memo Item (International bunkers) estimate.

Furthermore, the shipping methodology described above leads to a different domestic/international split in fuel use allocation for marine fuels compared with the allocations in the national energy statistics (DUKES) and submissions to IEA/EUROSTAT.

Estimation of Domestic and International Shipping Emissions from 1970-1990
For years prior to 1990, the implied emission factors and fuel types used for navigation are assumed to be the same as for 1990. Implied emission factors in g/kg fuel were developed for domestic, international and fishing vessels for gas oil and fuel oil.

The method for estimating fuel consumption by domestic, fishing and international shipping prior to 1990 is based on the relative share of these movement types in 1990 itself which was assumed to remain constant in all previous years. The 1990 share was applied to the total fuel consumption figures given in DUKES for each year back to 1970 (after deducting consumption by military vessels).

Summary of fuel consumption for UK marine activities
Table 3-43 summarises the time-series in gas oil and fuel oil consumption for domestic coastal and military shipping, fishing, inland waterways and international shipping and voyages from the UK to the OTs. These all refer to fuel sourced in the UK, so the sum is consistent with total fuel consumption figures reported in DUKES. Fuel consumed in the OTs and for voyages from the OTs to the UK are not included in this table.

Table 3-43 Fuel consumption for UK marine derived from inventory method

	Gas oil				Fuel oil		
ktonnes fuel	Domestic coastal and military	Fishing	Inland waterways	International bunkers	Domestic coastal and military	Voyages from UK to OTs	International bunkers
1990	0.609	0.025	0.090	1.595	0.35	0.008	1.124
1991	0.626	0.025	0.090	1.655	0.34	0.008	1.057
1992	0.588	0.025	0.091	1.681	0.34	0.008	1.087
1993	0.540	0.025	0.093	1.597	0.33	0.009	1.134
1994	0.521	0.025	0.097	1.526	0.35	0.009	0.941
1995	0.535	0.026	0.098	1.358	0.37	0.009	1.187
1996	0.540	0.034	0.099	1.574	0.37	0.009	1.249
1997	0.559	0.041	0.098	1.496	0.36	0.010	1.560
1998	0.450	0.038	0.099	1.791	0.37	0.011	1.406
1999	0.479	0.034	0.098	1.452	0.37	0.011	0.865
2000	0.461	0.032	0.099	1.462	0.35	0.012	0.618

	Gas oil				Fuel oil		
ktonnes fuel	Domestic coastal and military	Fishing	Inland waterways	International bunkers	Domestic coastal and military	Voyages from UK to OTs	International bunkers
2001	0.430	0.030	0.097	1.618	0.33	0.011	0.530
2002	0.413	0.029	0.098	1.209	0.35	0.008	0.452
2003	0.439	0.029	0.098	1.416	0.34	0.009	0.566
2004	0.469	0.028	0.100	1.319	0.34	0.010	0.925
2005	0.443	0.029	0.102	1.235	0.36	0.009	1.155
2006	0.427	0.038	0.103	1.652	0.34	0.013	1.468
2007	0.662	0.042	0.104	1.035	0.10	0.019	1.918
2008	0.649	0.074	0.103	0.860	0.10	0.011	2.448
2009	0.629	0.049	0.097	0.879	0.09	0.009	2.260
2010	0.616	0.064	0.099	0.803	0.09	0.011	1.845
2011	0.594	0.037	0.101	0.832	0.09	0.011	2.139

Summary of emission factors for UK marine activities

Table 3-44 shows the implied emission factors for each main pollutant, for both domestic and international vessel movements and fishing in 2011. The units are in g/kg fuel and are implied by the figures in the Entec study and fuel sulphur content..

Table 3-44 2011 Inventory Implied Emission Factors for Shipping

Fuel	Source	CH_4	N_2O	CO_2
		g/kg	g/kg	g/kg
Gas Oil	Domestic (excl. fishing)	0.05	0.08	870
	Fishing	0.05	0.08	870
	International	0.05	0.08	870
Fuel Oil	Domestic	0.05	0.08	879
	International	0.05	0.08	879

Fuel	Source	NO_X	SO_2	VOC	CO
		g/kg	g/kg	g/kg	g/kg
Gas Oil	Domestic (excl. fishing)	64.44	20.00	2.82	7.40
	Fishing	57.97	2.02	2.04	7.40
	International	69.33	20.00	2.74	7.40
Fuel Oil	Domestic	70.57	17.60	3.52	7.40
	International	77.71	27.60	2.92	7.40

Table 3-45 provides emission factors for each main pollutant, assumed for all vessel types operating on the UK's inland waterways in 2011.

Table 3-45 2011 Inventory Emission Factors for Inland Waterway Vessels

Fuel	CH_4	N_2O	CO_2
	g/kg	g/kg	g/kg
DERV	0.05	0.08	863
Gas Oil	0.05	0.08	870
Petrol	1.7	0.08	855

Fuel	NO_X	SO_2	VOC	CO
	g/kg	g/kg	g/kg	g/kg
DERV	42.5	0.0154	4.72	10.9
Gas Oil	42.5	0.02	4.72	10.9
Petrol	9.0	0.0096	50.0	300

3.2.11.3 Uncertainties and Time Series Consistency

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and fuel type.

Some of the core activity data for this source category are derived from DECC publication the Digest of UK Energy Statistics. **Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A. The sector allocation of gas oil consumption given in the DECC publication was not considered suitable for the inventory, so the 2010 inventory is derived from a different assignment using various estimation methodologies and data sources developed in a recent study on gas oil consumption across different sectors.

Other important sources of activity data are UK Department for Transport (DfT) publication Transport Statistics Great Britain and fuel consumption data supplied by the Ministry of Defence (Defence Fuels Group). Transport Statistics Great Britain is an established publication and the compilers of the activity data strive to use consistent methods to produce the activity data. Other statistical sources from the Department for Transport were used to provide time-series consistency in the approach used for shipping emissions while various other national statistics were used to derive time-series consistency in the new inventories for inland waterways and other off-road sectors.

In the current UK inventory there is a noticeable reduction in emissions from 2005 to 2006 despite a modest increase in aircraft movements and kilometres flown. This is attributable to the propagation of more modern aircraft into the fleet. From 2006 to 2007 there is a further reduction in emissions, which is attributable to both a modest decrease in aircraft movements and kilometres flown and the propagation of more modern aircraft into the fleet. In 2008, and again in 2009, there are reductions in both emissions and aircraft movements, in line with the economic downturn.

Within the time-series, emissions of N_2O from road transport are slightly higher in 2011 compared with 2010, this being due to the penetration of Euro V HGVs and buses which have higher N_2O emission factors than earlier Euro standards. This may be a result of more effective catalytic exhaust aftertreatment systems aimed at reducing NO_x emissions leading to higher N_2O emissions as a by-product. This is slightly offset by a reduction in the emissions from petrol cars due to a reduction in petrol car activity (as these are displaced by

diesel cars) combined with a reduction in the implied emission factor for petrol cars between 2010 and 2011 as older, higher emitting catalyst cars are displaced by newer cars.

Within the time-series, emissions of CH_4 from road transport are lower in 2011 compared with 2010. This is mostly due to a reduction in emissions from petrol cars which are the largest source of methane emissions from road transport. The decrease is due to a reduction in petrol car activity (as these are displaced by diesel cars) combined with a reduction in the implied emission factor for petrol cars between 2010 and 2011 as older, higher emitting cars are displaced by newer cars. The emission factors for newer cars are smaller due to tighter regulations on exhaust emissions of total hydrocarbons.

Methane emission factors for diesel vehicles are also smaller in 2011 than 2010 due to tighter regulations on exhaust emissions of total hydrocarbons. The high rate of change in implied emission factor for CH_4 from diesel used by road transport across the time series reflects the large decrease in emission factors for heavy duty vehicles. This is a consequence of the fleet penetration of new vehicles meeting the higher Euro standards with low g/km emission factors following the trends in total hydrocarbons. These factors show a 93-97% reduction in Euro IV emissions relative to Euro I.

The fluctuations in the time-series of emissions from navigation partly reflect the fluctuations in the total fuel consumption statistics for marine fuels given in DUKES. The time-series for national navigation is derived from trends in port activity statistics for different vessel types. Some of these show an increase in activities over time, others a decrease in activities over the time series. Further erratic behaviour in the time-series for bunker fuels results from the method used to introduce consistency with consumption data in DUKES. Further details in the methodology are given in the following sections on navigation.

The break in the time-series in national navigation emissions for residual oil and gas oil from 2007 onwards is due to the imposition of the Sulphur Emission Control Area (SECA) around UK waters from this year. It is assumed that the imposition of fuel sulphur content limits resulted in increased use of lower sulphur distillate (gas oil) compared with high sulphur residual oil. It was also assumed that passenger vessels switched from using residual oil to gas oil outside of SECAs from 2007 onwards to comply with the Sulphur Content in Marine Fuel Directive. As a consequence, the sum in emissions and fuel consumption from both fuels does not show a break, but there is an increase in gas oil emissions and a decrease in residual oil emissions from 2007.

3.2.11.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

3.2.11.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3-46** and emission factors in **Table 3-47** below. For information on the magnitude of recalculations to Source Category 1A3, see **Section 10**.

Summary of recalculations and methodology changes for Road Transport

There have been a number of improvements and revisions to input data made to the road transport inventory and the key changes are summarised as follows:

- Revised DUKES data for petrol and diesel sales (2007-2010), particularly for petrol sales in 2010 (3% lower compared to the value used in 2010 inventory).

- The Department for Transport (DfT) has revised minor road vehicle km estimates between 2000 and 2010 for England and Wales as a result of a benchmarking exercise carried out in 2010.
- Revised 2010 vehicle km activity data for Northern Ireland as provided by the Department for Regional Development.
- Revised assumption on the distribution of vehicle km between articulated HGVs 34-40t and 40-50t weight classes across the whole time series, based on bespoke licensing statistics provided by the DfT.
- Updated London bus fleet composition data as provided by Transport for London in July 2012.
- Corrected N_2O emission factors for coaches, London buses and rigid HGVs 3.5-7.5t and 7.5-12t weight classes.
- Corrected NO_x emission factors for small LGVs N1 (I) which are now based on medium sized-car emission factors.
- Revised total hydrocarbon (THC) emission factors which are now based on COPERT 4 v9.0.

For CO_2, these changes have affected the distribution of fuel consumption and hence CO_2 emissions between vehicle types. Total CO_2 emissions from road transport between 2007 and 2010 are slightly lower compared to the 2010 inventory, due to revised DUKES data for petrol and diesel sales as mentioned above. It should be noted that estimates of fuel consumption calculated for individual types of vehicles are normalised so the total adds up to the DUKES figures for petrol and diesel consumption (corrected for off-road consumption). For other pollutants where emissions are not directly related to fuel consumption, the changes in methods, activity data and emission factors alter the total emissions for road transport reported in each year.

For the OTs and CDs, there have been recalculations in this sector since the 2012 submission. The later time series (2008-2011) for Bermuda changed due to an updated time series provided by Bermuda for road transport fuel consumption data, 2009-2011, also leading to a change in the interpolation for the 2008 estimate. This update increased the consumption of petrol (by 17% in 2009) and decreased the consumption of diesel (by 62% in 2009). National navigation was a new source for the 2013 submission, taking into account emissions between the UK and the territories.

Table 3-46 1A3 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
1A3a	Aircraft - domestic cruise	Aviation turbine fuel	0.250	0.365	0.250	0.366	Mt fuel consumed	Error corrected in converting military fuel consumption data by financial year to calendar year. Reallocation of fuel between military and other aviation.
1A3b	Road Transport - Cars	Petrol	21.92	14.23	21.92	13.86	Mt fuel consumed	Revisions to fuel sales in DUKES and revisions to DfT mileage data by vehicle type
		DERV	0.87	7.30	0.87	7.11	Mt fuel consumed	
	Road Transport - LGVs	Petrol	1.99	0.27	1.99	0.26	Mt fuel consumed	Revisions to fuel sales in DUKES and revisions to DfT mileage data by vehicle type
		DERV	0.99	4.54	0.99	4.45	Mt fuel consumed	
	Road Transport - HGVs	DERV	7.49	7.27	7.50	7.40	Mt fuel consumed	Revisions to fuel sales in DUKES and revisions to DfT mileage data by vehicle type
	Road Transport - Buses	DERV	1.07	1.51	1.06	1.44	Mt fuel consumed	Revisions to fuel sales in DUKES and revisions to DfT mileage data by vehicle type
	Road Transport - Moped and Motorcycles	Petrol	0.198	0.183	0.197	0.178	Mt fuel consumed	Revisions to fuel sales in DUKES and revisions to DfT mileage data by vehicle type
1A3c	Railways - intercity	Gas oil	0.132	0.232	0.159	0.208	Mt fuel consumed	GHG Improvement Programme - Incorporation of output from DfT's Rail Emission Model (REM) with more detailed information on train km by different train classes on different routes.
	Railways - regional	Gas oil	0.148	0.203	0.142	0.224	Mt fuel consumed	
	Railways - freight	Gas oil	0.157	0.175	0.156	0.175	Mt fuel consumed	
1A3d	Inland waterways	DERV	0.028	0.092	0.028	0.094	Mt fuel consumed	Data for surrogate statistics updated for 2009 and 2010.
		Petrol	0.033	0.091	0.033	0.094	Mt fuel consumed	
	Shipping between UK and OTs	Fuel oil			0.014	0.021	Mt fuel consumed	New source included following 2012 In Country Review

Table 3-47 1A3 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
1A3a	Aircraft between UK and CDs/OTs	Carbon	Aviation Spirit	865	865	853	853	kt / Mt	Revised in order to be consistent with UK domestic and international aviation.
1A3b	Road Transport - Cars	N2O	DERV	0.000	0.138	0.000	0.137	kt / Mt	Revisions to DfT mileage data by vehicle type affect emission calculated by Tier 3 method and therefore IEF. More details of recalculations given in text
	Road Transport - LGVs	CH4	Petrol	0.884	0.148	0.885	0.203	kt / Mt	As for cars. Also corrected catalyst failure assumption
			DERV	0.198	0.021	0.198	0.020	kt / Mt	
		N2O	Petrol	0.106	0.115	0.107	0.119	kt / Mt	
	Road Transport - HGVs	CH4	DERV	0.438	0.077	0.438	0.076	kt / Mt	As for cars
		N2O	DERV	0.103	0.070	0.102	0.063	kt / Mt	As for cars. Also corrected emission factors for small weight classes <12t) of rigid HGVs
	Road Transport - Buses	CH4	DERV	1.253	0.146	1.251	0.146	kt / Mt	As for cars
		N2O	DERV	0.134	0.047	0.135	0.048	kt / Mt	As for cars. Also correctedemission factors for coaches and buses in London
	Road Transport - Moped and Motorcycles	CH4	Petrol	6.013	2.986	6.015	3.040	kt / Mt	As for cars. Also corrected factors for 2-st motorcycles
		N2O	Petrol	0.056	0.053	0.056	0.054	kt / Mt	As for cars. Also corrected factors on urban roads
1A3c	Railways - intercity	CH4	Gas oil	0.424	0.159	0.161	0.113	kt / Mt	GHG Improvement Programme - Incorporation of output from DfT's Rail Emission Model (REM)
		N2O	Gas oil	1.200	1.200	0.024	0.024	kt / Mt	GHG Improvement Programme - review of emission factors. Adopt EFs from 2009 EMEP / EEA Guidebook
	Railways - regional	CH4	Gas oil	0.297	0.384	0.253	0.099	kt / Mt	GHG Improvement Programme - Incorporation of output from DfT's Rail Emission Model (REM)
		N2O	Gas oil	1.200	1.200	0.024	0.024	kt / Mt	GHG Improvement Programme - review of emission factors. Adopt EFs from 2009 EMEP / EEA Guidebook
	Railways - freight	CH4	Gas oil	0.234	0.246	0.236	0.243	kt / Mt	GHG Improvement Programme - Incorporation of output from DfT's Rail Emission Model (REM)
		N2O	Gas oil	1.200	1.200	0.024	0.024	kt / Mt	GHG Improvement Programme - review of emission factors. Adopt EFs from 2009 EMEP / EEA Guidebook
	Rail - coal	Carbon	Coal	659.60	719.83	659.60	726.76	kt / Mt	Updated to be consistent with other UK coal consumption.

1A3d	Inland Waterways	Carbon	DERV	862.9	862.9	864.0	863.0	kt / Mt	Updated to be consistent with other UK DERV consumption.
	Shipping between UK and OTs	Carbon	Fuel oil			867	879	kt / Mt	New source included following 2012 In Country Review
		CH4	Fuel oil			0.05	0.05	kt / Mt	
		N2O	Fuel oil			0.08	0.08	kt / Mt	

3.2.11.6 Source Specific Planned Improvements

Emission factors, activity data and estimating methodology are continuously kept under review as new information emerges.

Most of the improvements in the transport sectors will depend on the availability of new or revised forms of activity data and emission factors and not all of these can be anticipated at this stage. Particularly for the road transport sector, the evidence to base changes in emission factors and new methods is a fast developing and changing area. A watching brief is kept on developments in emission factors and activity data for all modes of transport.

3.2.12 Source Category 1A4 – Other Sources

3.2.12.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1A4a: Miscellaneous	T1	CS
	Public Services	T1	CS
	Railways (Stationary Sources)	T1	CS
	1A4b: Domestic	T2	CS
	Domestic, House & Garden Machinery	T2, T3	CR, CS
	1A4c: Agriculture	T1	CS
	Agriculture Power Units	T2, T3	CR, CS
	Fishing	T2, T3	CR, CS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-oil, CO_2		
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-coal, CO_2 Stationary combustion-gas, CO_2 Stationary combustion-oil, CO_2		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	The activity data and emissions data in the CRF includes the components from the OTs and CDs for the relevant fuels.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	New sources for navigation: fishing in non-UK sea territories		

This source category covers emissions from fuel combustion by non-industrial sectors including commercial, agricultural and public sector use of fuels, as well as domestic sector energy use, and fuels used by fishing vessels. The estimates cover both fuels burnt in stationary plant, as well as gas oil and petrol used in mobile machinery, off-road vehicles and fishing vessels.

Most stationary plant are small-scale, apart from a few large installations providing energy for large commercial or public sector buildings. Emissions from railway sources are reported under 1A4a Commercial/Institutional in cases where these are anticipated to be from stationary sources e.g. the small-scale combustion of burning oil, and fuel oil, presumably for heating of buildings, as well as natural gas combustion. This gas usage may include fuel used for electricity generation for own use by the railway sector. The sector 'Miscellaneous' covers energy use by sectors covered elsewhere, for example fuels used in the sewage and refuse disposal sector, and fuels used by television and radio broadcasters.

Carbon emissions from the burning of lubricants in agricultural engines are also reported under 1A4. Separate estimates of non-CO_2 emissions from lubricant use are not included, as the emission factors derived for gas oil and petrol use in mobile machinery includes consideration of all fuel inputs to those engines, and hence to include factors from lubricants would introduce a double-count.

Emissions from mobile machinery used in agriculture and domestic house and gardens are reported under 1A4cii and 1A4bii, respectively.

The category 1A4ciii includes emissions from fishing vessels. Emissions from UK fishing vessels operating within UK waters have been reported in previous submissions, but for the first time in the 2013 submission the inventory agency includes estimates of emissions from UK fishing vessels operating outside UK waters. This improvement in the UK GHG inventory completeness for this source category was recommended by the UNFCCC Expert Review Team in 2012.

The NAEI category public service includes emissions from stationary combustion at military installations, which should ideally be reported under 1A5a Stationary. However, we do not have separate data for the military fuel component.

3.2.12.2 Methodological Issues

Table 3-48 summarises the methodologies used for the source categories reported under 1A4.

Table 3-48 Summary of Emission Estimation Methods for Source Categories in CRF Category 1A4

Source Category	Method	Activity Data	Emission Factors
Miscellaneous industrial /commercial combustion	AD x EF	DECC energy statistics	Carbon: UK-specific, including factors from coke manufacture carbon balance) CH_4, N_2O: IPCC, UK-specific
Public sector combustion	AD x EF	DECC energy statistics	
Railways - stationary combustion	AD x EF	DECC energy statistics	
Domestic combustion	AD x EF	DECC energy statistics	Carbon: UK-specific, including factors from coke manufacture carbon balance), default (IPCC) factors CH_4, N_2O: IPCC, USEPA, UK-specific
House and garden machinery	AD x EF	DECC energy statistics	Carbon: UK-specific CH_4, N_2O: UK-specific
Agriculture - stationary	AD x EF	DECC energy	Carbon: UK-specific, including

Source Category	Method	Activity Data	Emission Factors
combustion		statistics	factors from coke manufacture carbon balance) CH_4, N_2O: IPCC, UK-specific
Agricultural engines	AD x EF	Inventory agency estimate of fuel use by different mobile units	Carbon: UK-specific
Agriculture - mobile machinery	AD x EF	Inventory agency estimate of fuel use by different mobile units	Carbon: UK-specific CH_4, N_2O: UK-specific
Fishing vessels	AD x EF	Inventory agency estimate of fuel use across different shipping types, based on Entec 2010 study and DECC energy statistics	Carbon: UK-specific CH_4, N_2O: EMEP/EEA

For most sources, the estimation procedure follows that of the basic combustion module described in **Section 3.2.9.2.1**, using DECC reported fuel use data and emission factors from **Table A 3.2.2** to **Table 3.2.5**.

Emissions from 1A4b Residential and 1A4c Agriculture/Forestry/Fishing are disaggregated into those arising from stationary combustion and those from off-road vehicles and other machinery. Off-road machinery is a major user of gas oil and this section describes the method used to allocate gas oil consumption across a range of categories that are covered under other IPCC codes, including 1A2 and 1A3. These include sources that use gas oil for stationary combustion in the industrial, commercial and public sectors and for other mobile engines. However, the GHGI still maintains consistency with the total UK consumption of gas oil reported in DUKES.

The method for estimating emissions from fishing reported under 1A4ciii, including those from activities outside UK waters was described in **Section 3.2.11.2.6.**

The method used to estimate emissions from all other types of off-road machinery engines covered in 1A4, but also in 1A2 and 1A3 is also described in this section.

3.2.12.3 Treatment of Gas Oil in the inventory

Gas oil is used in both off-road transport and machinery diesel engines, and as a fuel for stationary combustion. The varied use of this fuel complicates the means of allocating consumption across the wide range of sectors that use the fuel in the inventory. DUKES provides a breakdown of gas oil consumption in different industry and other sectors, but with high uncertainty and DUKES is unable to distinguish between use of the fuel for stationary combustion and off-road machinery, a distinction which is necessary for the inventory.

The GHGI estimates consumption of gas oil and emissions for off-road machinery using a bottom-up method based on estimates of population and usage of different types of machinery. However, this has led to a situation where the total amount of gas oil consumption across sectors exceeds that which is available as given in DUKES. Therefore

consumption figures, mainly for stationary combustion in industry sectors, have had to be adjusted to obtain a total fuel balance.

The problem is extended when new sources of gas oil consumption are found. For example, the recent development of an inventory for the UK's inland waterways requires the allocation of gas oil to this sector (Walker et al, 2011). During the process of compiling the inland waterways inventory, it became clear that not all vessels with diesel engines use gas oil, but use road diesel and that this may also be the case for other off-road machinery sources, especially those that consume small amounts of fuel on an irregular basis, e.g. for private or recreational use rather than commercial use. There are also inconsistencies in terminology used to define types of fuel; it became apparent that the terms "gas oil", "red diesel" and "diesel" are used interchangeably by fuel suppliers and consumers and this confuses the situation when considering fuel allocations across different sectors.

In light of this, Task 5 of the 2011 UK GHG Inventory Improvement Programme aimed to address the allocation of gas oil and DERV in the GHGI (Murrells et al., 2011). The methodology outlined in Murrells et al. (2011) has been used in the compilation of the 2011 inventory, and is summarised here.

Several fuel suppliers and experts in the petroleum industry and at the Department for Transport were consulted to understand terminologies used, the physical differences between gas oil and DERV, and to gauge opinions on what determines where the fuels are mainly used where it is possible to use either gas oil or DERV. The study concluded that while the majority of agricultural and industrial machinery will be using low tax gas oil (red diesel), a small amount of DERV is likely to be used by private recreational boat users and by equipment with small engines used for private or small-scale commercial use on an irregular basis and the gas oil fuel supply infrastructure makes it more convenient to use DERV.

The study provided new estimates of the amount of DERV and petrol consumed by non-road transport sources with small internal combustion engines. This reduces the overestimation of gas oil consumption and relieves the pressure on how much gas oil consumption by other sources has to be adjusted to match the total amount available as given in DUKES.

The study also considered the allocation of gas oil given in DUKES to different industry and other sectors and how these can be mapped to inventory reporting categories. The detailed bottom-up method is used to estimate gas oil consumption by different off-road machinery and marine vessel types. Independent sources were used to estimate gas oil used by the rail sector while data provided by industrial sites reporting under emission trading schemes (EU ETS) were used to derive an allocation of gas oil consumption by stationary combustion sources in different industry, commercial and other sectors. Also, the UK energy statistics now include an allocation of gas oil for consumption by the oil and gas sector, but since only a partial time series was made available, the study included making estimates of gas oil for this category back to 1990.

A method of re-allocation was developed using an over-arching condition that the total sum of gas oil consumption across all sectors was consistent with the total consumption figures given in DUKES across all years. The method allowed the consumption estimates for industrial off-road machinery and stationary combustion by industry, commercial and public sector activities to vary in order to align the total consumption estimates with DUKES on the basis that the estimates for these sources are the most uncertain.

Details of the methodology were given in Murrells et al (2011). The report considers the uncertainties in the sector allocations and makes recommendations on how these can be improved based on current activities known to be taking place in the UK to understand the allocation of gas oil across some sectors. The method was first applied to the UK inventory reported in 2012 and the application of the method to define the allocation of gas oil consumption for all source categories across the time series from 1990-2010 was described in the last 2012 UK National Inventory Report. The same allocation method has been applied across the current time series for this version of the inventory.

3.2.13 Estimation of Off-Road Machinery Sources (1A2fii, 1A4bii, 1A4cii, 1A3e)

The following is a summary of the methods used to develop the inventory for off-road machinery and recalculations and methodological changes made in the 2013 submission of the inventory:

Summary of Methodology
A Tier 3 methodology is used for calculating emissions from individual types of mobile machinery, including those covered under 1A2fii (industrial and construction) and 1A3e (aircraft support).

Summary of emission factors
Machinery or engine-specific fuel consumption and emission factors (g/kWh) are taken from EMEP/CORINAIR Guidebook. Emission factors for more modern machinery based on engine or machinery-specific emission limits established in EU Non-Road Mobile Machinery Directive.

Summary of activity data
Bottom-up estimates from population and hours of use of equipment in 2004. Various proxy statistics used as activity drivers for different groups of machinery types to estimate fuel consumption in other years.

Summary of recalculations and methodology changes
No major recalculations or methodology changes used.

Details of Methodology
Emissions are estimated for 77 different types of portable or mobile equipment powered by diesel or petrol driven engines. These range from machinery used in agriculture such as tractors and combine harvesters; industry such as portable generators, forklift trucks and air compressors; construction such as cranes, bulldozers and excavators; domestic lawn mowers; aircraft support equipment. In the inventory they are grouped into four main categories:

- domestic house & garden – reported under 1A4b
- agricultural power units (includes forestry) – reported under 1A4c
- industrial off-road (includes construction and quarrying) – reported under 1A2f
- aircraft support machinery – reported under 1A3e.

Emissions are calculated from a bottom-up approach using machinery- or engine-specific emission factors in g/kWh based on the power of the engine and estimates of the UK population and annual hours of use of each type of machinery.

The emission estimates are calculated using a modification of the methodology given in EMEP/ CORINAIR (1996). Emissions are calculated using the following equation for each machinery class:

$$E_j = N_j \cdot H_j \cdot P_j \cdot L_j \cdot W_j.(1 + Y_j \cdot a_j /2). e_j$$

where

E_j	=	Emission of pollutant from class j	(kg/y)
N_j	=	Population of class j.	
H_j	=	Annual usage of class j	(hours/year)
P_j	=	Average power rating of class j	(kW)
L_j	=	Load factor of class j	(-)
Y_j	=	Lifetime of class j	(years)
W_j	=	Engine design factor of class j	(-)
a_j	=	Age factor of class j	(y^{-1})
e_j	=	Emission factor of class j	(kg/kWh)

For petrol-engined sources, evaporative NMVOC emissions are also estimated as:

$$E_{vj} = N_j \cdot H_j \cdot e_{vj}$$

where

E_{vj}	=	Evaporative emission from class j	kg
evj	=	Evaporative emission factor for class j	kg/h

The population, usage and lifetime of different types of off-road machinery were updated following a study carried out by Ricardo-AEA on behalf of the Department for Transport (Netcen, 2004a). This study researched the current UK population, annual usage rates, lifetime and average engine power for a range of different types of diesel-powered non-road mobile machinery. Additional information including data for earlier years were based on research by Off Highway Research (2000) and market research polls amongst equipment suppliers and trade associations by Precision Research International on behalf of the former DoE (Department of the Environment) (PRI, 1995, 1998). Usage rates from data published by Samaras *et al* (1993, 1994) were also used.

The population and usage surveys and assessments were only able to provide estimates on activity of off-road machinery for years up to 2004. These are one-off studies requiring intensive resources and are not updated on an annual basis. There are no reliable national statistics on population and usage of off-road machinery nor figures from DECC on how these fuels, once they are delivered to fuel distribution centres around the country, are ultimately used. Therefore, other activity drivers were used to estimate activity rates for the four main off-road categories from 2005-2011.

For industrial and construction machinery, a set of four drivers is used. Each of the individual machinery types is mapped to one of these four drivers depending on the typical industry sector in which the machinery type is usually used. The four categories and drivers used are described in Table 3-49.

For domestic house and garden machinery, trends in number of households are used (CLG, 2011), for airport machinery, statistics on number of terminal passengers at UK airports are used (CAA, 2012), and for agricultural off road machinery, the trends in gas oil allocated to agriculture in DUKES (DECC, 2012) are used.

A simple turnover model is used to characterise the population of each machinery type by age (year of manufacture/sale). For older units, the emission factors used came mostly from EMEP/CORINAIR (1996) though a few of the more obscure classes were taken from Samaras & Zierock (1993). The load factors were taken from Samaras (1996). Emission factors for garden machinery, such as lawnmowers and chainsaws were updated following a review by Netcen (2004b). For equipment whose emissions are regulated by Directive 2002/88/EC or 2004/26/EC, the emission factors for a given unit were taken to be the maximum permitted by the directive at the year of manufacture. The emission regulations are quite complex in terms of how they apply to different machinery types. Each of the 77 different machinery types was mapped to the relevant regulation in terms of implementation date and limit value.

The methodology follows the Tier 3 methodology described in the latest EMEP/EEA emission inventory guidebook (EMEP/EEA, 2009).

Table 3-49 Activity drivers used for off-road machinery in the industry and construction sector.

Category	Driver source	Machinery types
Construction	ONS construction statistics. The value of all new work (i.e. excluding repair and maintenance work) at constant (2005) prices and seasonally adjusted. Taken from the Construction Statistics Annual. The 2012 Annual did not include the seasonally adjusted output, therefore the non-seasonally adjusted figures were used and scaled to ensure time series consistency. http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-260307	generator sets <5 kW
		generator sets 5-100 kW
		asphalt pavers
		tampers /rammers
		plate compactors
		concrete pavers
		rollers
		scrapers
		paving equip
		surfacing equip
		trenchers
		concrete /industrial saws
		cement & mortar mixers
		cranes
		graders
		rough terrain forklifts
Quarrying	Data on UK production of minerals, taken from UK Minerals Yearbook data, BGS 2012.	bore/drill rigs
		off highway trucks*
		crushing/processing equip
Construction and Quarrying	Growth driver based on the combination of the quarrying and construction drivers detailed above.	excavators
		loaders with pneumatic tyres
		bulldozers
		tracked loaders
		tracked bulldozers
		tractors/loaders
		crawler tractors
		off highway tractors
		dumpers /tenders
General Industry	Based on an average of growth indices for all industrial sectors, taken from data supplied by DECC for use in energy and	generator sets 100-1000KW
		pumps
		air compressors
		gas compressors

Category	Driver source	Machinery types
	emissions projections.	welding equip
		pressure washers
		aerial lifts
		forklifts*
		sweepers/ scrubbers
		other general industrial equip
		other material handling equip

Aggregated emission factors for the four main off-road machinery categories in 2011 are shown in **Table 3-50** by fuel type. DERV emission factors for all pollutants except for carbon and SO_2 have been corrected for the 2013 submission. A problem with the model had led to an over estimation of these emission factors for the 2012 submission and this has now been corrected.

The emission factors shown here for 2011 are generally the same as or lower than the factors for 2010. This is a consequence of the penetration of new machinery meeting the tighter emission regulations in the non-road mobile machinery fleet. The factors for SO_2 in 2011 are considerably lower than those for 2010. This is because the maximum permitted sulphur content of gas oil used for off-road machinery was reduced to 10ppm from 1 January 2011 in accordance with EU Fuel Directive 2009/30/EC. Data on the sulphur content of fuels from UKPIA refer to gas oil used for stationary heating and rail not affected by the Directive in 2011. In absence of actual data, the SO_2 factor here refers to the maximum sulphur content of 10ppm.

Table 3-50 Aggregate Emission Factors for Off-Road Source Categories in 2011 (t/kt fuel)

Source	Fuel	C[2]	CH_4	N_2O	NO_x	CO	NMVOC	SO_2[3]
Domestic House&Garden	DERV	863	0.16	1.31	47.96	4.34	2.57	0.02
Domestic House&Garden	Petrol	855	0.80	0.03	3.43	667.85	40.42	0.01
Agricultural Power Units	Gas oil	870	0.16	1.32	22.82	16.81	4.32	0.02
Agricultural Power Units	Petrol	855	2.17	0.02	1.45	716.32	248.58	0.01
Industrial Off-road	DERV	863	0.14	1.27	33.70	16.12	6.51	0.02
Industrial Off-road	Gas oil	870	0.14	1.27	33.70	16.12	6.51	0.02
Industrial Off-road	Petrol	855	3.76	0.05	6.24	1034.72	39.33	0.01
Aircraft Support	Gas oil	870	0.15	1.34	23.58	12.52	4.37	0.02

1 Emission factors reported are for 2011
2 Emission factor as kg carbon/t, UKPIA (2004)
3 Based on sulphur content of fuels in 2011 from UKPIA (2012).

The emission factors used for carbon were the standard emission factors for DERV, gas oil and petrol given in **Table 3-50.**.

Emission factors for carbon are almost exclusively based on UK source data, and are typically fuel-specific defaults based on information from fuel suppliers. Factors for coal are also sector-specific, taking into account the varying quality (e.g. calorific value) of coals supplied to different sectors. Methodologies for the derivation of factors for most fuels are

given in Baggott *et al*, 2004. Factors for coke used in 1A4 are based on the carbon balance approach described in Section 3.2.7.2.1. Site-specific data, for example from EU ETS sources, are not used in the derivation of factors for 1A4 because any relevant fuel use in EU ETS would only constitute a very small fraction of total fuel use in the 1A4 category and therefore could not be considered representative. For example, a small number of combustion installations at hospitals and university buildings report to EU ETS, but use only a tiny fraction of the total fuel consumed by the UK public sector.

There were no emissions in 1A4c estimated for any overseas territories or crown dependencies due to a lack of available data. Fuel consumption data were obtained from national statistics. These data do not necessarily cover the entire time series so interpolation and extrapolation are applied to produce a complete time series. Some territories do not provide fuel consumption for these specific activities so it is assumed that any remaining fuel after power generation has been excluded is used within this sector. UK GHGI emission factors are applied to these activity data for all sources. These estimates are compiled by Aether and Ricardo-AEA.

3.2.13.1 Uncertainties and Time Series Consistency

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and fuel type.

Most of the core activity data for this source category is derived from the DECC publication the Digest of UK Energy Statistics. **Section 3.5** provides further general information about the time series consistency of activity data in this publication, and provides more general comments on the approaches used to ensure time series consistency in source category 1A.

3.2.13.2 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

3.2.13.3 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3-51** and emission factors in **Table 3-52** below. For information on the magnitude of recalculations to Source Category 1A4, see **Section 10**.

For the OTs and CDs, there have been recalculations in this sector since the 2012 submission. There was an increase of 11% to all emission estimates in Guernsey across the time series. This was due to the updated activity data for power generation, which then affected the interpolation used to create a consistent time series. This submission also saw the Falkland Islands emissions increase by 32% from natural gas for the domestic sector. This affected the latter part of the time series: 2008-2011, and was due to new activity data being submitted by the territory, overriding previous estimates based on extrapolation.

Table 3-51 1A4 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
1A4a	Miscellaneous industrial/commercial combustion	Natural gas	1668	1787	1668	1784	Mth fuel consumed	DUKES activity data revised for 2010
	Public sector combustion	Gas oil	0.53	0.03	0.53	0.02	Mt fuel consumed	Revisions to the gas oil reallocations due to various updates to data
		Natural gas	1207	1462	1207	1454	Mth fuel consumed	DUKES activity data revised for 2010
1A4b	Domestic combustion	Natural gas	10274	13324	10274	13349	Mth fuel consumed	DUKES activity data revised for 2010
		Charcoal			0.053	0.106	Mt fuel consumed	Additional activity data included for charcoal use. Highlighted as an issue by other member states at Working Group 1 meeting during 2012.
1A4c	Agriculture - stationary combustion	Straw	0.19	0.45	0.19	0.49	Mt fuel consumed	DUKES activity data revised for 2010
	Fishing vessels	Gas oil	0.006	0.004	0.025	0.064	Mt fuel consumed	Additional activity data included for deep sea fishing in non-UK waters as a result of recommendations from the 2012 In Country Review. These activity data reallocated from international shipping

Table 3-52 1A4 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
1A4a	Miscellaneous industrial/commercial combustion	Carbon	Coal	659.6	611.6	659.6	612.5	kt / Mt	Revision to GCVs quoted in UK energy statisitcs
		Carbon	Coke	813.2	852.4	813.2	853.6	kt / Mt	Inclusion of updated energy data in the coke & steelmaking carbon balance, leading to revised carbon factor for coke.
	Public sector combustion	Carbon	Coal	659.6	611.6	659.6	612.5	kt / Mt	Revision to GCVs quoted in UK energy statisitcs
		Carbon	Coke	813.2	852.4	813.2	853.6	kt / Mt	Inclusion of updated energy data in the coke & steelmaking carbon balance, leading to revised carbon factor for coke.
	Railways - stationary combustion	Carbon	Coke	813.2	852.4	813.2	853.6	kt / Mt	Inclusion of updated energy data in the coke & steelmaking carbon balance, leading to revised carbon factor for coke.

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
1A4b	Domestic combustion	Carbon	Coal	676.8	667.8	676.8	668.2	kt / Mt	Revision to GCVs quoted in UK energy statisitcs
		Carbon	Coke	813.2	852.4	813.2	853.6	kt / Mt	Inclusion of updated energy data in the coke & steelmaking carbon balance, leading to revised carbon factor for coke.
		CH4	Charcoal	NA	NA	6.00	6.00	kt / Mt	New data data included for charcoal use. Highlighted as an issue by other member states at Working Group 1 meeting during 2012.
		N2O	Charcoal	NA	NA	0.03	0.03	kt / Mt	
1A4c	Agriculture - stationary combustion	Carbon	Coke	813.2	852.4	813.2	853.6	kt / Mt	Inclusion of updated energy data in the coke & steelmaking carbon balance, leading to revised carbon factor for coke.

3.2.13.4 Source Specific Planned Improvements

Research is planned into the energy data for used for public sector emissions, although the scope of this work is not yet finalised. Emission factors and activity data are kept under review. For full details of the improvement programme see **Section 1.2.2.5**.

3.2.14 Source Category 1A5 – Other

3.2.14.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1A5b: Aircraft Military Shipping Naval	T3 T2	CS, D CS, D
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O Stationary combustion-oil, CO_2		
Key Categories (Level)	1A1, 1A2, 1A4, 1A5 Other Combustion, N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	No emissions reported separately – all included within UK emission totals.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements.		

3.2.14.2 Methodological Issues

Emissions from military aircraft and naval vessels are reported under 1A5b Mobile. The method of estimation is discussed in the **Section 3.2.11.2.1** on aviation (1A3a) and **Section 3.2.11.2.6** on navigation (1A3d), respectively. Note that military stationary combustion is included under 1A4a Commercial and Institutional due to a lack of more detailed data.

3.2.14.3 Uncertainties and Time Series Consistency

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and fuel type.

3.2.14.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

3.2.14.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3-53** and emission factors in **Table 3-54** below. For information on the magnitude of recalculations to Source Category 1A5, see **Section 10**.

3.2.14.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review. If appropriate, fuel characterisation data from verified Emission Trading System datasets will be considered in future GHGI cycles.

Table 3-53 1A5 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
1A5b	Aircraft - military	Aviation turbine fuel	1.234	0.652	1.234	0.638	Mt fuel consumed	Error corrected in converting military fuel consumption data by financial year to calendar year.

Table 3-54 1A5 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
1A5b	Aircraft - military	Carbon	Aviation spirit	865	865	853	853	Mt fuel consumed	Revised in order to be consistent with other UK aviation spirit combustion.

3.3 FUGITIVE EMISSIONS FROM SOLID FUELS OIL AND NATURAL GAS (CRF 1.B)

3.3.1 Source category 1B1 – Solid Fuels

3.3.1.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1B1a: Deep-Mined Coal	T3	CS
	Coal Storage & Transport	T2	CS
	Open-Cast Coal	T2	CS
	1B1b: Charcoal Production	T1	IPCC
	Coke Production (Fugitive)	T3	CS, OTH
	SSF Production (Fugitive)	T3	CS, OTH
	Iron & steel flaring (Coke Oven Gas)	T3	CS, OTH
	1B1c: Closed Coal Mines	T3	CS
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions from 1B1b – charcoal production, included for the Falkland Islands		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	**1B1a**: Improved accuracy and completeness due to revision to emissions from deep-mined coal production to use methane emissions data from a greater share of the UK colliery industry than previously. **1B1b**: Improved completeness, due to inclusion of emissions from charcoal production.		

This source category covers emissions which occur during the production, transportation or use of solid fuels but which are not due to the combustion of those fuels. These emissions include the release of methane contained within coal and emissions of carbon and organic compounds during the transformation of coal into coke and solid smokeless fuels (SSF). Emissions also occur from the flaring of waste gases during coke and SSF manufacture.

In 2011 there were 13 deep-mining collieries operational, of which 4 have methane drainage and recovery systems used to collect and burn mines gas to raise power. A further 31 open cast coal mines were also operating in the UK in 2011. This is compared with 188 deep mining collieries and 126 open cast mines operating in 1990[30].

The reported emission trends for deep-mined coal in the UK reflect the decline in activity since the base year, with activity in 2011 (7.3 Mt coal) only 10% of that in 1990 (73 Mt coal).

[30] http://coal.decc.gov.uk/assets/coal/DyGgJafg_pdf_part.pdf

The decline in open-cast production is much less marked, with production in 2011 (10.6 Mt) 58% of that in 1990 (18.1 Mt).

3.3.1.2 Methodological Issues

1B1a Coal Mining and Handling

1B1ai Underground mines, Mining Activities: Deep-mined coal.
1B1ai Underground mines, Post-Mining Activities: Coal storage and transport.
1B1aii Surface Mines, Mining Activities: Open-cast coal.

Emissions are calculated from saleable coal production statistics reported by DECC (2012). For all sources, UK-specific emission factors are applied, which in the early part of the time series are derived from periodic industry publications, and for later years (1998 onwards) are primarily derived from company-specific or mine-specific reporting of methane emissions by mine operators. Industry-wide colliery methane utilisation data are taken from DUKES (DECC, 2012).

From 1990-1995, a small number of "deep mines" operated in the UK were privately owned, shallower and smaller mines. These mines were licensed by the UK Government and in all years produced less than 3% of total UK deep-mined coal, whilst the majority of deep mines were Government-owned and operated. Research from 1995 indicated that these smaller licensed mines emitted less methane than the nationalised deeper mines, and therefore the aggregate emission factor for the early part of the time series is slightly lower. Activity data for production at licensed mines is taken from Barty (1995), with the activity data for non-licensed mines calculated by difference from the UK deep-mine coal production total in UK energy statistics.

Emission factors for methane from **deep-mined coal** production are taken from:

1990-1992 Bennet et al (1995) was a study on deep mines which produced estimates of emissions for the period 1990-93. This was a period over which significant numbers of mines were being closed, hence the range in emission factors from 10 to 13.1 kg CH_4 per tonne coal extracted.

1990-1995 The methane emission factor of 1.36 kg CH_4/tonne coal produced at licensed, shallow mines is from Williams (1993).

1993-1997 No time series of emissions data or industry research for deep-mined mines are available for 1993-97, and therefore the 1998 factor from operator reporting at deep mines (see below) is used. The combination of this 1998 factor for deep-mined coal and the lower factor for licensed, shallow mines operating to 1995 leads to a variable aggregate factor during 1993-1995.

1998-2011 The emission factors for UK mines in 1998-2011 are based on operator measurements of the methane extracted by the mine ventilation systems for all collieries operated by UK Coal (UK Coal, 2012) and for collieries owned by other operators that report methane utilisation and venting data (Coal Authority, 2012). Not all UK collieries provide data on methane utilisation and venting. The emission factor derived from the sites that provide data is applied across all UK production at deep mined sites. The proportion of UK production that is covered by the reporting collieries ranges from 77% in 1998 to 96% in 2004 and 2007, and is around 90% since 2008.

Methane extracted at deep mines is either emitted into the atmosphere or utilised for energy production; the gas is not flared for safety reasons. Data provided by colliery operators provides mine-specific annual data on the mass of methane:

- vented to atmosphere, fan drift (A)
- drainage to surface (B)
- utilisation of methane in electricity generation (C)

The total methane vented to atmosphere is therefore calculated as “A + B – C”.

The decline in methane emissions in recent years in the UK reflects both the decline in UK deep-mined coal production and the increase in uptake of technology to utilise coal mine methane to generate electricity.

The emission factor for methane from **coal storage and transport** factor of 1.16 kg CH_4 per tonne of coal produced is only applied to deep mined coal production and is taken from industry research, Bennet et al (1995).

The emission factor for methane emissions from **open cast coal production** of 0.34 kg CH_4 per tonne of coal production is taken from industry research, Williams (1993).

The reported activity data in the CRF Table 1B1 for UK coal production used in the derivation of fugitive methane emission estimates comprises data for coal production at deep-mined and open-cast sites. In the UK energy balance, there is an additional line for coal production which is for “other” sources of coal into the UK economy, which are typically very small numbers (735 kt in 2011) and represent coal obtained from slurries, ponds and rivers. We therefore include the activity data for "other" sources of coal within the UK energy balance, as part of the overall supply of coal as reported in the CRF table 1.Ab, but we do not derive any estimates of fugitive emissions from this production source, as it is not coal that has been abstracted from open cast or deep mines. This leads to an apparent discrepancy in reported activity data between the CRF tables 1B1 and 1Ab. In 2011, the activity data in table 1B1 (excluding the coal from slurries / ponds) is 17.89 Mt, whereas the activity data in table 1Ab (including all UK coal sources) is 18.63 Mt. Similar reporting differences are evident across other years in the CRF.

1B1b Solid Fuel Transformation

Fugitive emissions from solid fuel transformation processes are reported in IPCC category 1B1b. The IPCC Revised 1996 Guidelines do not provide any methodology for such estimates, hence emissions are largely based on default emission factors.

Charcoal production.

Emissions from **charcoal production** are included in the UK GHG inventory for the first time in the 2013 submission. Emission estimates are based on UK activity data on charcoal production from FAOSTAT Forestry Production and Trade Statistics (FAO, 2012). These data were available for the UK and the Falkland Islands but not for and other overseas territories or crown dependencies. The methane emission factor of 30 kt per Mt charcoal produced is derived from the default emission factors in table 1.14 of the IPCC 1996 Guidelines and an estimated NCV of charcoal of 30 MJ/kg from table 1.13 of the IPCC 1996 Guidelines.

Coke production.

Carbon emissions from coke ovens are based on a carbon balance approach (discussed in **Section 3.2.10**) with calculations arranged so that the total carbon emission, plus carbon in products and wastes, corresponds to the carbon content of the input raw materials. Emissions from the combustion of coke oven gas and blast furnace gas within the coke oven are based on this carbon balance approach, which allocates output carbon between the coke and gases, and is influenced by the default carbon factor applied for the coking coal input to the process.

For process emissions from coke ovens for other pollutants, emissions are estimated either on the basis of total **production of coke** or the coal consumed. Emission factors are provided in **Annex 3**, **Table A 3.2.9**.

The methane emission factor of 0.0802 kt per Mt coke produced is taken from the EIPPCB, Best Available Techniques Reference Document on the Production of Iron & Steel, March 2000 (EIPPCB, 2000).

Solid smokeless fuel production.
Emissions of carbon from **Solid Smokeless Fuel (SSF) production** are also based on a carbon balance approach, as discussed in **Section 3.2.10**. For other pollutants, estimates are either made based on a mass balance approach (for sulphur dioxide) or on SSF production data and emission factors as provided in **Table A 3.2.9**.

There are a number of processes used in the UK ranging from processes similar to coking to briquetting of anthracite dust and other smokeless fuels. Given the range of processes in use, these estimates will be very uncertain. It is possible that some emissions from SSF manufacture could arise from the combustion of gases produced during SSF manufacturing processes e.g. gases evolved from retorts used to manufacture some fuels. However, this combustion is not identified in the energy statistics and so emissions from SSF manufacture are treated as fugitive and reported under 1B1b.

Combustion emissions from use of coal in fuel transformation to produce SSF are reported within 1B1b, whereas combustion of gas and coke oven coke are treated as energy uses and are reported under 1A1c. Activity data for coal use in SSF manufacture are taken from UK energy statistics, DUKES (DECC, 2012), combining the sum of steam coal and anthracitic coal used in SSF manufacture. The emission factor is derived from the carbon balance approach which calculates total carbon lost (i.e. emitted) during the SSF manufacturing process, by subtracting the carbon retained in the SSF product from the sum of carbon inputs.

The methane emission factor of 0.0802 kt per Mt coke produced is taken from the EIPPCB, Best Available Techniques Reference Document on the Production of Iron & Steel, March 2000 (EIPPCB, 2000) and applied to the SSF production.

Iron and steel flaring of coke oven gas.
The activity data for **coke oven gas flaring in the iron and steel industry** is taken from the UK energy statistics, DUKES (DECC, 2012).

The carbon factor for coke oven gas is derived from the iron and steel integrated steelworks mass balance, as outlined in **Section 3.2.10**.

The methane emission factor of 0.00604 kt per Mth and the nitrous oxide emission factor of 0.00021 kt per Mth are taken from the factors presented for COG use in blast furnace cowpers in the EMEP-CORINAIR guidebook from 2003.

1B1c Other Fugitive Emissions from Solid Fuels
Closed coal mines.
Methane emissions from **closed coal mines** are accounted for within Sector 1B1c of the UK inventory. Emission estimates are based on a recent study funded by DECC (WSP, 2011) which updated research from 2005 (White Young Green, 2005) to:

- reflect the UK trend in mine closures and re-openings driven by fluctuations in energy prices since the 2005 research; and

- improve the representation of methane recovery and utilisation at closed collieries (emissions from the combustion of colliery methane are included in the energy sector, 1A)

The 2011 study derived estimates for historic methane emissions from closed coal mines and also generated projections to 2050, based on forecasts for UK coal mining activity. The 2011 emission estimates in this 2013 UK GHGI submission are therefore taken from the projections of emissions within the 2011 WSP report.

The UK model that was developed in 2005 and revised in 2011 generates both historic and projected methane emission estimates from closed UK coal mines, combining two separate sets of calculations to estimate emissions from:

- coal mines that were closed before 2005 and included in the 2005 update; and
- mines that were not included in the 2005 update, including mines closing or predicted to close between 2004 and 2028

Methane emissions from closed mines reach the surface through many possible flow paths: vents, old mine entries, diffuse emission through fractured and permeable strata. Direct measurement of the total quantity of gas released from abandoned mines is not practical. The model uses a relationship between emissions and the quantity of the underlying methane gas within the abandoned mine workings, including site-specific considerations of the most appropriate decay model for the recently closed mines. The 2011 study used the same method, updating data for mine closures during 2005-2010. The research also includes benchmarking of UK specific estimates with other inventories to ensure that the method used remains appropriate for the UK.

The model calculates methane reserves for all UK coalfields that are not totally flooded from 1990 with projections to 2050. The gas reserves are calculated by totalling all the gas quantities in individual coal seams likely to have been disturbed by mining activity. To enable calculation of the reserves over time, the rise in water levels in the abandoned mines due to water inflow has been calculated based on industry consultation, with a date estimated for each of the mines to be fully flooded; as mine workings become flooded they cease to release significant amounts of methane to the surface.

The development of the model has drawn on industry monitoring to measure methane emission from vents and more diffuse sources, including measurement of the flow rate and methane concentrations of vented mine gases. The industry knowledge of these methane sources has increased greatly in the UK over the last 10 years as the technology to capture and utilise the methane for power generation has developed alongside new economic incentives to utilise the mine methane in this way. Monitoring of more diffuse sources involves the collection of long-term gas samples to measure any increases in background atmospheric methane level in the locality.

Methane flows measured by both methods showed a general increase with the size of the underlying gas reserve. The data indicate an emission of 0.74% of the reserve per year as a suitable factor to apply to the methane reserve data in order to derive methane emission estimates for abandoned UK coalfields for 1990 to 2050, and this factor is applied within the model to derive the UK emission estimates.

Estimates have been made for both deep mined and open cast coal.

Table 3-55 Summary of data for closed coal mines (kt CH_4)

	1990	1995	2000	2005	2010	2011
Cumulative Number of Mine Areas Closed	**121**	**132**	**138**	**144**	**148**	**148**
Deep Mine Methane Emissions Estimates	**52.83**	**97.66**	**70.04**	**49.95**	**48.85**	**45.37**
	±8.46	±16.11	±11.50	±7.39	±6.30	±5.79
Open Cast Mine Methane Emissions Estimates	**3.08**	**2.78**	**2.28**	**1.78**	**1.62**	**1.62**
	±0.62	±0.56	±0.46	±0.36	±0.32	±0.32
Total All Mines Methane Emissions Estimates	**55.91**	**100.45**	**72.32**	**51.72**	**50.47**	**46.99**
	±8.48	±16.11	±11.50	±7.39	±6.31	±5.80
Methane Utilisation	**-4.72**	**-4.72**	**-14.15**	**-31.00**	**-33.02**	**-28.52**
	±0.25	±0.25	±0.75	±1.64	±1.75	±1.51
% Methane Utilised (UK)	9%	5%	20%	62%	68%	63%
Net Methane Emissions	**51.20**	**95.73**	**58.17**	**20.72**	**17.45**	**18.47**
	±8.48	±16.12	±11.53	±7.57	±6.55	±5.99

3.3.1.3 Uncertainties and Time Series Consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

Most of the core activity data for this source category is derived from the DECC publication the Digest of UK Energy Statistics, with additional detail on coal mined in deep mines and open cast mines from the UK Coal Authority which has a statutory duty to regulate the industry and report on activities.

Section 3.5 provides further general information about the time series consistency of activity data in DUKES, and provides more general comments on the approaches used to ensure time series consistency in source category 1B.

The time series emission factors used in this source category are presented in **Annex 3, Section A3.3.3.** The factors for coal mining are all based on UK industry research. Emission factors from coal storage and transport, licensed mines and from open cast mines do not vary through the time series; in each case the same factor is applied to the UK activity in every year. For deep-mined coal emissions there is a variable emission factor across the time series, derived from operator reporting and reflecting the changing methane management practices within UK collieries, especially to increase methane capture and oxidation for power-raising in recent years, leading to a gradually declining methane emission factor per unit coal produced since the early 2000s. The variability in the factor also reflects the changes in production from different mines that have different methane management practices, as for some UK collieries the capture and use of methane has not proved cost-effective and therefore the technology is not uniformly implemented.

All of the non-CO_2 emission factors from sources in solid fuel transformation are from literature sources, with no variability across the time series. Emissions of CO_2 from these sources are based on a UK model that applies a carbon balance across all inputs and outputs in these fuel transformation sources.

3.3.1.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Activity data for coal production in deep-mined and open-cast mines in the UK are quality-checked through comparison of data reported within DUKES and data reported directly by the UK Coal Authority, which provides regional and UK totals of coal production. The information provided directly by colliery operators regarding their methane recovery systems are also checked against the data published by DECC on coal mine methane projects in the UK (which encompasses both operating and closed / abandoned mines with coal mine methane recovery systems).

3.3.1.5 Source Specific Recalculations

1B1ai Underground mines, Mining Activities: Deep-mined coal.

A revision has been made to the methane emissions time series in recent years to use data from more companies other than UK Coal. This has improved the accuracy of the inventory estimates, as the emission factor is now derived from site-specific data that represents a greater share of UK production at deep mines than in previous submissions.

The calculations in the 2012 submission assumed that emission factors derived from UK Coal collieries (~80% of the industry) were representative of the whole UK industry. Stakeholder consultation has identified data on methane emissions vented at some additional collieries in the UK, although we still do not have reporting on methane emissions from all UK collieries. In 2011, the collieries used to generate the UK emission factor for methane emissions from deep-mined coal cover 90% of total UK production.

This improvement has led to slightly higher emissions since 2007, mainly due to new data for one high-emitting colliery that had previously been owned by UK Coal.

A method revision in the calculations has also had a minor impact on the 2013 submission data. In previous submissions the estimates of methane released by coal mines was based on operator data of the volume of gases emitted, and a conversion factor was then used to determine the mass of methane emitted, assuming STP and applying the Relative Molecular Mass of methane. For the 2013 submission, we have accessed data direct from operators on the mass of methane released, removing the need for additional factors and calculation steps to convert from volume to mass terms.

Note also that the improvement in reporting transparency to report emissions from closed coal mines in source category 1B1c, rather than within 1B1a as in previous submissions, has re-allocated emissions between those two source categories, i.e. reduction in 1B1a and an equal and opposite increase in 1B1c. There has been no revision to the closed coal mine methane emission estimates in this submission, aside from this reporting re-allocation.

Details of and justifications for recalculations to activity data are given in **Table 3-56** and emission factors in **Table 3-57** below. For information on the magnitude of recalculations to Source Category 1B1, see **Section 10**.

3.3.1.6 Source Specific Planned Improvements

Emission factors and activity data are kept under review. For full details of the improvement programme see **Section 1.2.2.5**.

Stakeholder consultation with the mining industry will continue to seek greater representation of UK-wide mining activities, to ensure that the methane emissions from deep-mined coal reflect the practices across the country. The current IEF is based on data from around 90% of UK deep-mined collieries.

Table 3-56 1B1 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
1B1b	Charcoal production	Charcoal	NA	NA	0.000	0.005	Mt	Additional activity data included for charcoal production. Highlighted as an issue by other member states at Working Group 1 meeting during 2012.

Table 3-57 1B1 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
1A1a	Deep-mined coal	CH4	Coal produced	10.00	7.53	10.00	9.39	kt / Mt material produced	Improved accuracy of UK-specific factors due to use of methane emissions data from more UK deep mine operators. Previous submission assumed data from UK Coal was representative of the whole industry. Now have around 90% coverage of the industry in deriving the emission factor.
1B1b	Charcoal production	CH4	Charcoal	NA	NA	30.00	30.00	kt / Mt	New source in the 2013 submission. Have applied default factor from the IPCC 1996 Guidelines.

3.3.2 Source category 1B2 – Oil and Natural Gas

3.3.2.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	1B2a: Oil Production - well testing	T2	CS, PS
	Oil Production – process and fugitive emissions	T2	CS, PS
	Oil Production – offshore oil loading	T3	CS
	Oil Production – onshore oil loading	T3	CS
	Refineries (drainage)		
	Refineries (tankage)		
	Refineries (process)		
	Oil Production - oil terminal storage	T2	CS
	Petroleum processes		
	Petrol Stations (Petrol Delivery)		
	Petrol Stations (Vehicle Refuelling)		
	Petrol Stations (Storage Tanks)		
	Petrol Stations (Spillages)		
	Petrol Terminals (Storage)		
	Petrol Terminals (Tanker Loading)		
	Refineries (Road/Rail Loading)		
	1B2b: Gas production –well testing	T2	CS, PS
	Gas production – gas terminal storage	T2	CS, PS
	Gas production – process and fugitive emissions	T2	CS, PS
	Gasification processes		
	Gas transmission network leakage	T3	CS
	Gas distribution network leakage	T3	CS
	Gas leakage at point of use	T3	CS
	1B2c: Oil production – gas venting	T3	CS, PS
	Gas production – gas venting	T3	T3
	Oil production – gas flaring	T3	T3
	Refineries (Flares)		
	Gas production – gas flaring	T3	T3
Gases Reported	CO_2, CH_4, N_2O, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No estimates of emissions are made for oil and gas well blow-outs. These are infrequent, unplanned incidents for which there is no IPCC method and no routine emissions data gathering / reporting in the UK. Work is underway to estimate emissions from this source.		

	A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	Review of time series of EEMS-reported data, to address (mainly) outlier IEFs from combustion sources in 1A1c, but this review has also identified some mis-allocations of facilities and emissions between upstream oil and upstream gas and a small number of facility reporting gaps in the 1B2 source categories – now resolved. Review of time series of gas leakage from the UK gas distribution network, leading to revisions in estimates for 1993-2002 inclusive. Improved transparency in reporting of emissions from the gas supply network in the UK, with new separate estimates of leakage from the gas transmission system (1B2biii), which previously was reported with distribution leakage in 1B2biv. Improved completeness of reporting of gas leakage at point of use, including new estimates of leakage from gas use in cooking appliances in residential and commercial sectors.

This source category covers emissions which occur during the production, transportation, or use of liquid and gaseous fuels but which are not due to the combustion of those fuels to support a productive activity.

In the UK, 1B2 emissions occur from:

- oil and gas production facilities;
- gas and oil terminals;
- gas processing facilities;
- oil refineries;
- gas transmission networks;
- storage and distribution of petrol; and
- gas leaks at the point of use (i.e. leaks from residential and commercial gas appliances).

Emissions from fuel combustion at upstream oil and gas production facilities is reported within IPCC source category 1A1c Other Energy Industry; emissions reported in 1B2 comprise process, fugitive, venting and flaring emissions.

UK upstream oil and gas exploration and production is almost entirely offshore, with a very small number of onshore oil wells also evident; no onshore gas production occurs in the UK, although shale gas reserves have been identified and some preliminary research into prospective shale gas extraction is on-going within UK Government and industry.

Offshore oil and gas is transported to processing plants via pipelines and marine tankers; emissions of CH_4 and VOC occur during loading of oil into the ship's tanks, and then subsequently at the unloading stage to onshore storage vessels, whilst emissions of VOC occur from storage tanks at oil terminals.

Fugitive emissions trends from the upstream oil and gas sector reflect the changes in UK production through the time series. Oil production in 2011 (2266 PJ) is 57% of that in 1990 (3981 PJ), whilst gas production peaked in the UK in 2000 (4083 PJ), and by 2011 production (1704 PJ) is much lower and very close to that in 1990 (1709 PJ). Overall emissions from the upstream source categories (i.e. from exploration/well testing to terminals) across the oil and gas sector have remained at a relatively stable level per PJ production, with emissions of GHGs (across oil and gas sources) in 1990 of 14.3 kt CO_2e / PJ (oil and gas) compared to 13.4 kt CO_2e / PJ (oil and gas) in 2011.

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Note that the data reported on gas throughput in the CRF Table 1B2 for 2011 is 1704 PJ, and represents the upstream gas production throughput on a net energy basis. In the CRF Table 1.Ab, the UK gas production total for 2011 is presented as 526,699 GWh, which equates to 1896 PJ, but this figure includes the production of colliery methane that is generated in the UK and used directly on colliery sites to provide power and heat (and therefore there are no transmission and fugitive release estimates from this source).

Emissions of CO_2, CH_4, CO, N_2O, NO_x, SO_2, and VOC occur at refineries due to venting of process plants for reasons of safety, from flaring of waste products, leakages from process plants, evaporation of organic contaminants in refinery wastewater, regeneration of catalysts by burning off carbon fouling, and storage of crude oil, intermediates, and products at refineries.

Distribution of petroleum products in the UK is typically via road and rail tankers from refineries to approximately 60 petrol/diesel terminals for storage prior to distribution to end users (primarily petrol stations), via road tankers. At petrol stations the oil products are stored and then dispensed into the fuel tanks of road vehicles. Emissions of VOC occur from each storage stage and from each transfer stage.

An additional source of GHG emissions from oil & gas exploration that is not included within the UK inventory is the release of methane-containing gases from underground reservoirs following drilling blow-outs at the seabed. Well blow-out emissions are not routinely reported by operators via the UK environmental regulatory systems, nor is there an IPCC methodology to derive estimates for this source, and hence no estimates of mass emissions from well blow-outs are currently included in the UK GHG inventory.

3.3.2.2 Methodological Issues

An overview of the data sources and methods used to derive estimates for the 1B2 sources in the UK is presented in the table below. (Related 1A1 sources are included also, for reference and completeness):

Table 3-58 Summary of Data Sources and Estimation methods for 1B2 source categories in the UK GHG Inventory, 1990-2011

Type of facility / source	IPCC source categories	Data Sources and Methods
Offshore oil and gas platforms	[1A1c Other Energy industry: Upstream oil/ gas fuel use (diesel, own gas)]	Primarily based on DECC energy stats, however some gaps in data on gas use (1990-2001) and LPG/OPG use (2003-) are addressed using EU ETS and EEMS data.
	1B2aii, 1B2bii Oil, Gas Production: Upstream facility process and fugitive releases	1998-2011: sum of reported facility emissions for process and fugitive releases (EEMS). 1990-1997 data based on UKOOA 2005 study. Source allocation less certain for earlier years.
	1B2aiii Transport: Offshore loading of oil	1998-2011: sum of reported facility activity and emissions for offshore loading (EEMS). 1990-1997 emissions data based on UKOOA 2005 study. AD estimated assuming CH_4 IEF from 1998 is valid for earlier years.
	1B2ci,ii Venting at upstream oil, gas facilities	1998-2011: sum of reported facility emissions for venting releases (EEMS). 1990-1997 data based on UKOOA 2005 study. Source allocation less certain for earlier years.
	1B2ci,ii Flaring at upstream oil, gas facilities	1997-2011: sum of reported facility activity and emissions for flaring (EEMS). 1990-1996 emissions data based on UKOOA 2005 study, with mass-based AD estimated from the DECC volume time-series, assuming the same oil:gas split as in EEMS 1997, and aggregate oil and gas flaring volumes 1990-2011 (DECC 2012).
Offshore floating production and storage vessels, well testing rigs	[1A1c Other Energy industry: Upstream oil/ gas fuel use (diesel, own gas)]	[As above for oil and gas platforms]
	1B2ai, 1B2bi Oil, Gas Exploration: well testing	1998-2011: sum of reported facility activity and emissions for well testing (EEMS). 1990-1997 emissions data based on UKOOA 2005 study. AD estimated assuming CO_2 IEF from 1998 is valid for earlier years.
	1B2aii, 1B2bii Oil, Gas Production: Upstream facility process and fugitive releases	[As above for oil and gas platforms]
	1B2aiii Transport: Offshore loading of oil	[As above for oil and gas platforms]

Type of facility / source	IPCC source categories	Data Sources and Methods
	1B2ci,ii Venting at upstream oil, gas facilities	[As above for oil and gas platforms]
	1B2ci,ii Flaring at upstream oil, gas facilities	[As above for oil and gas platforms]
Onshore oil and gas terminals, onshore oil wells	[1A1c Other Energy industry: Upstream oil/ gas fuel use (diesel, own gas)]	As above for oil and gas platforms, except that where terminals do not report to EEMS (post-2009), the source estimates for own fuel use are based on EU ETS data (where available), with overall facility emissions aligned with IPPC/EPR-reported data (EA and SEPA, 2012).
	1B2aii, 1B2bii Oil, Gas Production: Upstream facility process and fugitive releases	As above for oil and gas platforms, but missing sites from EEMS are estimated based on IPPC/EPR-reported data (EA and SEPA, 2012). Source-specific estimates more uncertain for these sites where EEMS data missing.
	1B2avi Other: Onshore loading of oil	As above for the loading estimates for oil and gas platforms, but again – where EEMS data is absent the overall facility emissions are aligned with IPPC/EPR inventories and therefore source-specific estimates are uncertain.
	1B2ci,ii Venting at upstream oil, gas facilities	As above for venting estimates for oil and gas platforms, but where EEMS data is absent the overall facility emissions are aligned with IPPC/EPR inventories and therefore source-specific estimates are uncertain.
	1B2ci,ii Flaring at upstream oil, gas facilities	Flaring emissions estimated as above for offshore oil and gas platforms, except where terminals do not report to EEMS since 2010. EU ETS data on flaring are used if available. Where no EEMS or EU ETS data are available, an estimate of the total reported emissions in IPPC are allocated to flaring.
Refineries	[1B1b Petroleum refineries]	1990-2011 Combustion emissions estimated using UK energy statistics (DECC, 2012), augmented by trade association emissions data (UKPIA, 2012) and since 2005 the EU ETS dataset on fuel use and emissions (EA, SEPA and NIEA, 2012). Emission factors are taken from UKPIA compositional analysis, carbon factors review (2004) and EU ETS.
	1B2aiv Refining /	1990-2011 Fugitive emissions from oil storage

Type of facility / source	IPCC source categories	Data Sources and Methods
	Storage: Petroleum processes, Oil Terminal storage	and refinery processes are derived from aggregate industry estimates provided by the refinery trade association (UKPIA, 2012).
UK oil distribution network	1B2av Distribution of Oil Products (no direct GHG emission sources)	Road and rail taker loading (UKPIA, 2012). Storage and loading at petrol terminals and petrol stations: method from Institute of Petroleum 2000 and CONCAWE (1986), input data from UKPIA (2012), DECC (2012), Met Office (2012).
UK gas transmission network	1B2biii Transmission: High pressure transmission network leakage	1990-2011 Gas network leakage data estimated directly by the gas network operators, using an industry leakage model and periodic surveys of the gas network (in 1992, 2002). Estimates include leakage from the transmission pipelines only. Activity data in the CRF present the total gas delivery in the UK via the network, but these data are not directly used in the calculations to derive leakage estimates.
UK gas distribution network and associated above ground installations, e.g. gas compressors	[1A1c Other energy industry: Gas combustion in gas network compressors]	1990-2011 Activity data from national energy statistics (DECC, 2012), augmented since 2005 by EU ETS data on gas use at gas compressor stations (EA, SEPA, NIEA 2012). Emission factors taken from gas compositional analysis from gas network operators (National Grid, Northern Gas Networks, Scotia gas, Wales and West, 2012).
	1B2biv Distribution: Low pressure distribution network leakage	1990-2011 Gas network leakage data estimated directly by the gas network operators, using an industry leakage model and periodic surveys of the gas network (in 1992, 2002). Estimates include leakage from the low pressure gas distribution pipelines and also from other sources such as Above Ground Installations on the grid. Activity data in the CRF present the total gas delivery in the UK via the network, but these data are not directly used in the calculations to derive leakage estimates.
Residential and commercial gas users	1B2dv Other Leakage: Gas leakage at point of use	1990-2011 Activity data on gas use in residential and commercial sectors, DUKES (DECC, 2012) Emission factors derived using assumptions of leakage rates of different types of appliance to derive an overall estimate of percentage total gas leaked.

Upstream Oil and Gas Emission Sources: Overview of Emissions Reporting

As noted in the table above, many of the 1B2 source estimates in the UK GHGI are derived from operator-reported activities and emissions from the upstream oil and gas facilities that are regulated by the DECC Offshore Inspectorate. Oil and gas operators submit annual source-specific emission estimates to DECC in the Environmental Emissions Reporting System (EEMS); reporting of emissions is mandatory for all offshore facilities, whilst onshore oil and gas terminals report on a voluntary basis as they are regulated under Integrated Pollution Prevention and Control (IPPC) Regulations by the onshore regulatory agencies, SEPA and the Environment Agency of England and Wales. Operator emissions reporting under IPPC is installation-wide (i.e. aggregated for each pollutant across all sources, not providing source-specific detail) and therefore the allocation of emissions across combustion, process and fugitive sources within the national inventory is more uncertain for onshore facilities such as terminals.

The EEMS Reporting System

Emissions from upstream oil and gas production facilities, including onshore terminals, are estimated based on operator reporting via EEMS, regulated by the DECC Offshore Inspectorate and developed in conjunction with the trade association Oil & Gas UK (formerly the UK Offshore Operators' Association, UKOOA). The EEMS data provides a detailed inventory of point source emissions estimates, based on operator returns for the years 1995-2011; the EEMS data for 1995 to 1997 inclusive are not complete, frequently exhibit duplicate entries with identical submissions by operators across years, nor are they consistent with data from 1998 onwards and hence the EEMS dataset is only used directly to inform national inventory estimates from 1998 onwards. Additional data on CO_2 emissions from some offshore combustion processes has become available via the National Allocation Plan and annual operator emission estimates for sites participating in the EU Emission Trading System.

The EEMS dataset are considered the primary dataset to inform UK GHG inventory estimates as they are source-specific, complete (cover all emission sources on each facility), transparent (activity data and emissions data reported for most sources) and have been reported by operators for around 15 years. The EU ETS data cover a smaller scope of installations and of sources within those installations[31], but the EU ETS data are verified by third parties and are therefore useful to use as a quality check for the combustion and flaring emissions source estimates within the national inventory.

Environmental reporting by oil and gas terminals in the UK includes:

- Annual reporting of emissions by pollutant aggregated across all emission sources under the IPPC/ EPR reporting system to the Environment Agency of England and Wales, or to SEPA. These data are available from 1998 in England and Wales and for 2002 and 2004 onwards in Scotland and include emission estimates for a suite of GHG and air quality pollutants including CO_2, CH_4 and N_2O;
- For 1995 to 2009, all terminals also reported source-specific emission estimates to the EEMS system, but from 2010 this was determined to be on a voluntary basis only, and therefore from 2010 onwards the EEMS dataset is incomplete for terminals. For combustion and flaring sources, the EEMS dataset includes mass-based activity

[31] EU ETS data for upstream oil and gas facilities include combustion sources during 2005-7 (Phase 1 EU ETS) and combustion and flaring sources in 2008-11 (Phase II EU ETS). The EU ETS reporting scope excludes other GHG emission sources such as venting, process sources, fugitives, well testing emissions and methane from oil loading / unloading and oil storage.

data, as well as emission estimates for a suite of GHG and air quality pollutants including CO_2, CH_4 and N_2O;
- From 2005 onwards, combustion CO_2 emissions at terminals have been reported under EU ETS, and from 2008 onwards combustion and flaring CO_2 emissions at terminals has been reported under EU ETS. The scope is not as comprehensive as EEMS or IPPC, but the data are useful to check carbon emission factors and to inform a de-minimis emission value for each site.

Therefore, for oil and gas terminals the EU ETS data provides useful additional detail, where facilities may not report to EEMS but do report facility-wide (i.e. aggregated across all sources) emission estimates under IPPC/EPR. The EU ETS data provides emission estimates that can be broken down by fuel and between combustion and flaring sources, to augment the IPPC emissions data.

The inventory compilation method was overhauled in the 1990-2007 submission, to take advantage of developments in the EEMS dataset from the DECC Offshore Inspectorate, which enabled greater access to reported activity data that have been used to calculate the emissions for the following sources:

- Gas flaring;
- Own gas combustion;
- Well testing; and
- Oil loading (onshore and offshore)

[Activity data are not routinely collected via EEMS for sources including: fugitive releases, direct process activities, oil storage or gas venting. The emissions from these sources are reported as annual estimates by operators and used directly within the inventory.]

These EEMS-derived activity data enable greater analysis of the oil & gas emissions and related emission factors at the installation level, providing a high degree of data transparency and improving the level of detail for performing quality checks by source, by site, by year. For those sources, this has led to an improvement in data transparency and easier query of Implied Emission Factor trends. However, the EEMS activity data are only available back to 1998, and hence the activity data back to 1990 are extrapolated using the oil and gas production time-series that were collected at that time for the purposes of energy data reporting.

UK Energy Statistics Data for Oil and Gas Activities

The Petroleum Processing Reporting System (PPRS) is the mechanism by which upstream oil and gas operators are required to report energy and other activity data to the DECC Energy Statistics team as part of the wider system of regulation of the oil & gas extraction and production sector, and to inform upstream energy market trends. These data reported by oil and gas companies via the PPRS include data on **gas flaring volumes** at offshore and onshore installations, as well as oil and gas production data. It is these data (that are collected independently of the EEMS environmental data) that are used to extrapolate the activity data back to 1990.

Inventory Compilation Approach: Quality Assurance of EEMS

The EEMS dataset quality system is managed by the regulatory agency (DECC) and developed in conjunction with the trade association (UK Oil & Gas). EEMS uses an online reporting system with controls over data entry, together with guidance notes provided to

operators to provide estimation methodology options and emission factors for specific processes.

The inventory agency combines UK energy statistics, the EEMS data, EU ETS and IPPC data to derive the oil and gas sector estimates. The data reported from the EEMS system must be reconciled with the UK Energy Statistics and integrated into the NAEI without double-counting emissions. Where the EU ETS or IPPC data are inconsistent with the EEMS data, the inventory agency works with the DECC Offshore Inspectorate and facility operators to determine the best available data for each source. The inventory agency also conducts time-series consistency checks to identify missing sites or sources, and for those sources where the EEMS data includes emissions and activity data the inventory agency reviews the time series of implied emission factors to identify outliers. Any sites or sources where the quality checks identify gaps, outliers or inconsistent reporting between different regulatory systems are resolved in consultation with the DECC Offshore Inspectorate.

Reference Sources for Upstream Oil and Gas Emission Estimates, 1990-1997

The operator-reported emission estimates within EEMS area available from 1995 onwards, but as noted above are not comprehensive and consistent until 1998 onwards. The UK GHG inventory estimates for EEMS emission sources during 1990-1997 inclusive are based on industry estimates provided within periodic reports in the 1990s, with a comprehensive review and update by the trade association provided in 2005 (UKOOA, 2005). This 2005 update was based on a UKOOA report from 1998, updated to use latest emission factors and activity data from across the sector.

The 1998 UKOOA report presents data from detailed industry studies in 1991 and 1995 to derive emission estimates for 1990 from available operator estimates. Emission estimates for 1991-1994 were then calculated using production-weighted interpolations. Only limited data were available from operators in 1990-1994, and emission totals were only presented in broadly aggregated sectors of: drilling (offshore), production (offshore), loading (offshore) and total emissions onshore. Emission estimates for the more detailed oil & gas processing sources (well testing, fuel combustion, flaring, venting, process and fugitive, oil loading / unloading and oil storage) were then based on applying the fraction of total emissions derived from the 1997 data from EEMS.

In the 2013 submission, the source estimates from this 2005 update from UKOOA have been retained, with the exception of the fuel combustion emission estimates, due to the identified under-report in DUKES activity data for natural gas use from oil and gas terminals during 1990-2000 inclusive (DECC, 2012). In this instance, the inventory agency notes that the previous (i.e. UKOOA 2005) estimates were made based on incomplete activity data and therefore new estimates have been derived and reported within source category 1A1c.

Allocation to Upstream Oil and Upstream Gas Source Categories

During 2010, analysis was completed in consultation with oil and gas industry regulators and operators to allocate each installation to either the oil or gas industry, in order that separate emission estimates may be derived from the EEMS dataset and reported in the appropriate IPCC sectors. For installations where oil and gas are co-produced in associated terminals, regulator information has been used to assess whether the site is predominantly an oil or gas production installation. This improvement has led to much more detailed reporting of emissions, greater transparency of emission estimates and will also improve the accuracy of the UK GHG emission estimates by end user categories, as the emissions from upstream oil and upstream gas industry can now be managed separately. This development enables the UK GHG inventory agency to report emissions separately between 1B2a and 1B2b source

categories (whereas previously the gas production estimates were combined with the equivalent oil production source categories). In the latest cycle, one correction to this allocation has been made, as one offshore facility that is a gas-producing site had previously been misallocated to the upstream oil sector.

For the years 1990 to 1997 inclusive, the installation-specific EEMS data were not available (1990-1994) or are not regarded as a good quality dataset (1995-1997). The allocation of sites to oil and gas industries does not therefore provide an improvement to the detail or transparency of the estimates in the early part of the time series. This is unfortunate, but the data simply do not exist to generate any more accurate, detailed estimates. In order to present a plausible trend in overall emissions for the oil and gas sectors back to 1990, a relatively simplistic approach has been adopted to divide the industry estimates between oil and gas back to 1990.

For flaring, gas consumption and well testing emissions the oil:gas ratio of activity data in 1998 has been used to extrapolate back the activities to 1990, retaining the previous emission factors for the "oil and gas" sources. For process and fugitive sources, oil storage and venting emissions, where the EEMS data are simply presented as emissions data without any underlying activity and emission factor information, the estimates for the early part of the time series are simply based on the oil:gas ratio (for each pollutant) from 1998.

Exploration: Well testing in Oil (1B2ai) and Gas (1B2bi)

The emissions from well testing are predominantly from the combustion of gases in on-site flares, with an industry assumption that the flares are 98% efficient. Therefore operators report a 2% non-combusted gas release, plus the flaring emissions. The emissions are allocated in 1B as they are a combination of flaring and fugitive releases and are associated with upstream oil and gas exploration and production.

Well testing is an activity that is not recorded within the Digest of UK Energy Statistics. Activity and emissions data for CO_2, SO_2, NO_x, CO, NMVOC, and CH_4 are taken from the EEMS dataset (DECC, 2012) for 1998 onwards, whilst emissions for 1990-1997 are taken from UKOOA estimates (UKOOA, 2005). The activity data for 1990-1997 has been estimated using the carbon factor from 1998, i.e. on the assumption that the carbon emission factor remains constant back to 1990. These calculations indicate possible inconsistencies in emissions data within the earlier years of the time-series, most notably for emissions of SO_2 during 1990-1997 and for N_2O during 1990-1994.

The activity data and implied emission factors are presented in Annex 3 in **Table A 3.2.20 and Table A 3.2.21**.

Oil Loading Emissions: 1B2aiii Transport (offshore loading) and 1B2avi Other (onshore loading)

This emission source comprises CH_4 and NMVOC releases from tanker loading and unloading based on data from the EEMS dataset (DECC, 2012). Data from 1998-2011 are based on detailed operator returns, whilst 1990-1997 data are based on trade association estimates (UKOOA, 2005). In recent years, the methane and NMVOC data from operators appear to be incomplete in the EEMS dataset, most notably from ship loading emissions at BP sites (onshore terminals and offshore platforms). The inventory agency has added estimates in such instances, extrapolating emission estimates from earlier years. These emission totals for methane and NMVOCs are therefore subject to considerable uncertainty.

Activity data (tonnes oil loaded / unloaded) are available from the EEMS dataset for 1998 onwards, whilst the activity data for 1990-1997 are not available from industry reports and has therefore been estimated, based on the assumption that the methane emission factor remains constant back to 1990. This approach enables a transparent assessment of implied emission factors for 1998 onwards.

The activity data and implied emission factors are presented in Annex 3 in **Table A 3.2.22**.

The 2011 onshore loading factor for NMVOC is notably lower due to lower emissions reported at the ConocoPhillips terminal at Seal Sands, Teesside; the IEF for NMVOC at that site is 60% lower than in previous years. The 2011 offshore loading factor for methane is higher than previous years due to a high report of methane releases from the Gannet Alpha platform; high NMVOC emissions are also reported from that platform, but the factor is comparable to other years due to several platforms and FPSOs applying IEFs that are lower than in 2010 including Pierce, Anasuria and Curlew.

Flaring: Oil (1B2ci) and Gas (1B2cii)

This emission source includes flaring of waste gases at offshore platforms and at onshore terminals. Flaring emission data for CO_2, SO_2, NO_x, CO, NMVOC, and CH_4 are taken from the EEMS dataset (DECC, 2012). Data from 1997-2011 are based primarily on detailed operator returns held within the EEMS dataset. In some cases, for onshore terminals, the allocation of emissions to "flaring" is uncertain, where source-specific reporting through EEMS is not available and estimates are made based on EU ETS and/or IPPC emissions totals.

Total flaring emissions estimates for the oil and gas sector for 1990-1996 data are taken from periodic reports by the trade association, UKOOA, with flaring emission estimates back to 1990 provided in 2005 (UKOOA, 2005). The allocation of flaring emissions to upstream oil and upstream gas sectors are derived using the 1997 split of oil:gas within the facility-specific EEMS data.

The activity data and implied emission factors are presented in Annex 3 in **Table 3.3.52 and Table 3.3.53**. The implied emission factors for 1997-2011 are reported as kg pollutant per kg gas flared and are calculated from emissions and activity data reported annually by operators via the EEMS reporting system. The data for 1990-1996 are estimated based on reported emission totals (UKOOA, 2005) and extrapolated activity data. From 1990 onwards there is a full time series of gas flaring volumes for the oil and gas sector published by DECC (DECC, 2012), and this is used in conjunction with the EEMS data on mass of gas flared in 1997 to derive estimates of the mass of gas flared back to 1990.

Note that an estimate of NMVOC emissions from refinery flares is also reported in 1B2ci Venting and Flaring: Oil. This is based on estimates supplied by UKPIA (2012).

Other Upstream Oil and Gas Emission Sources

Other GHG emission sources from upstream oil and gas facilities that are estimated based on industry data and operator reporting, without underlying activity data include:

1B2aii Oil Production

- Fugitive emissions (CO_2, CH_4, NMVOC estimates only);
- Direct process emissions, such as acid gas stripping plant at terminals (CO_2, NO_X, SO_2, CO, CH_4, NMVOC);

1B2aiv Oil Refining / Storage

- Storage vessel emissions from the storage of crude oil at terminals (CH_4, NMVOC estimates only);

1B2bii Gas Production / Processing

- Fugitive emissions (CO_2, CH_4, NMVOC estimates only);
- Direct process emissions, such as acid gas stripping plant at terminals (CO_2, NO_X, SO_2, CO, CH_4, NMVOC);

1B2c Venting

- Gas Venting (CO_2, CH_4, NMVOC estimates only) at upstream oil facilities (1B2ci)
- Gas Venting (CO_2, CH_4, NMVOC estimates only) at upstream gas facilities (1B2cii)

Emissions data are taken from the EEMS dataset (DECC, 2012) and previous industry studies by the upstream oil and gas trade association (UKOOA, 2005). Data for 1998-2011 are based on detailed operator returns, whilst 1990-1997 data are based on the UKOOA submission in December 2005 which updated previous industry studies that calculated source emission estimates from extrapolation of total emissions data and the use of 1997 data splits between sources.

Note that there are no activity data for these activities available from DECC or UK Oil & Gas; UK GHGI estimates are the aggregated operator emissions reported via the EEMS system or from the UKOOA 2005 data submission. From 1998, the method is simply:

UK GHGI = ∑ facility emissions in EEMS (by source)

The inventory agency conducts annual quality checks to assess the completeness of reporting by facilities, and time series consistency checks. However, in the absence of any other industry activity data, there is a reliance on operators to use the available reporting guidance and EEMS templates to provide full and accurate emission estimates for use in the inventory.

Gaps in reported fugitive & storage tank emissions by certain operators and sites are evident in recent years, and where possible, data have been extrapolated from previous years to provide estimates to fill these gaps. There have also been some significant changes in activities at some sites that have led to notable emission reductions in recent years, including reduction of direct process emissions of SO_2 at the Elgin PUQ platform, due to a change to venting acid gases rather than flaring them.

1B2aiv Refining / Storage: Refinery and Petroleum Process Emissions

This source category includes estimates of NMVOC emissions from oil refineries due to venting of process plant for reasons of safety, from flaring of waste products, leakages from process plant, evaporation of organic contaminants in refinery wastewater, regeneration of catalysts by burning off carbon fouling, and storage of crude oil, intermediates, and products at refineries. In the UK inventory these emission sources are aggregated under:

- Refineries (drainage);
- Refineries (tankage); and
- Refineries (process).

All are based on UKPIA (2012) estimates for 1994-2011. The UKPIA data refer to the following UK refinery installations:

- Texaco, Milford Haven;
- Elf, Milford Haven;
- BP, Coryton;
- Shell, Shell Haven (closed during 1999);
- Conoco, South Killingholme;
- Lindsey, Killingholme;
- Shell, Stanlow;
- PIP, North Tees;
- Esso, Fawley;
- BP, Grangemouth; and
- Gulf, Milford Haven (closed during 1997).

UKPIA also supply estimates for loading of petrol into road and rail tankers at refineries. Prior to 1994, process emissions are estimated by extrapolation from the 1994 figure on the basis of refinery throughput, whereas emissions from tankage, flares and drainage systems are assumed to be constant.

Also included under 1B2aiv Refining and Storage are NMVOC emissions from petroleum processes including:

- specialist refineries (Llandarcy, Eastham, Dundee, & Harwich)
- onshore oil production facilities
- miscellaneous petroleum processes not covered elsewhere in the inventory (e.g. Kimmeridge and Horndean well sites)

Emissions are taken from the Pollution Inventory (Environment Agency, 2012). No emissions data have been found for the Dundee refinery.

Petrol Distribution, 1B2av

Petrol distribution begins at refineries where petrol may be loaded into rail or road vehicles. Petrol is distributed to approximately 60 petrol terminals where it is stored prior to loading into road tankers for distribution to petrol stations. At petrol stations it is stored and then dispensed into the fuel tanks of road vehicles. Emissions of NMVOC occur from each storage stage and from each transfer stage.

The UK inventory includes emissions from the storage, distribution and sale of petrol in the following categories each of which is further divided into emissions of leaded and unleaded petrol:

- Refineries (Road/Rail Loading). Emissions during loading of petrol on to road and rail tankers at refineries;
- Petrol Terminals (Storage). Emissions from storage tanks at petrol distribution terminals;
- Petrol Terminals (Tanker Loading). Emissions during loading of petrol on to road and rail tankers at petrol terminals;
- Petrol Stations (Petrol Delivery). Emissions during loading of petrol from road tankers into storage tanks at petrol stations;
- Petrol Stations (Storage Tanks). Emissions from storage tanks at petrol stations;
- Petrol Stations (Vehicle Refuelling). Emissions due to displacement of vapour during the refuelling of motor vehicle at petrol stations; and

- Petrol Stations (Spillages). Emissions due to spillages during refuelling of motor vehicles at petrol stations.

Emissions also occur from storage tanks at refineries. This source is included together with emissions from the storage of crude oil and other volatile materials in the NAEI source category, refineries (tankage).

The emission estimates from road and rail tanker loading at refineries are supplied by UKPIA (2012). The remaining estimates are based on methodologies published by the Institute of Petroleum (2000) or, in the case of petrol terminal storage, based on methods given by CONCAWE (1986). The calculations require information on petrol density, given in DECC (2012), and petrol Reid Vapour Pressure (RVP), data for which have been obtained from a series of surveys carried out by Associated Octel between 1970 and 1994.

More recent, detailed RVP data are not available, but UKPIA have suggested values for 1999 onwards. Central England Temperature (CET) data (Met Office, 2012) are used for ambient UK temperatures. The methodology also includes assumptions regarding the level of vapour recovery in place at terminals and petrol stations. These assumptions draw upon annual account surveys carried out by the Petroleum Review (2000 onwards) that include questions on petrol station controls, and the timescales recommended in Secretary of State's Guidance for petrol terminals (PG 1/13 (97)). The activity data are the sales of leaded and unleaded petrol from DECC (2012).

Gasification Processes, 1B2bii

This source category includes NMVOC emissions from onshore gas production facilities, refining and odourisation of natural gas, natural gas storage facilities, and processes involving reforming of natural gas and other feedstock to produce carbon monoxide and hydrogen gases. Emissions are taken from the Pollution Inventory (Environment Agency, 2012) and Scottish Pollutant Release Inventory (SEPA, 2012). For the years prior to 1994, they are extrapolated based on gas throughput. Care is taken to avoid double counting with the upstream oil and gas exploration and production emissions.

Leakage from Natural Gas Transmission (1B2biii) and Distribution (1B2biv) Networks

The UK GHG inventory sources of natural gas leakage from the downstream gas supply system covers emissions of CH_4 and NMVOC from the UK gas transmission and distribution networks. Annual activity data and gas compositional analysis are provided by National Grid Gas, four companies (formed in 2005) that operate the low-pressure gas distribution networks within Great Britain, and also from Phoenix Gas in Northern Ireland. The leakage estimates are determined in three parts, reported in the CRF as follows:

1B2biii Transmission

- Losses from High Pressure Transmission Mains (National Grid Gas);

1B2biv Distribution

- Losses from Low Pressure Distribution Network (National Grid Gas, Scotia Gas, Northern Gas Networks, Wales & West, Phoenix Gas);
- Other losses, from medium pressure gas mains, Above Ground Installations (AGIs), AGI working losses and interference (National Grid Gas, Scotia Gas, Northern Gas Networks, Wales & West, Phoenix Gas).

The gas network operators provide annual gas leakage estimates on a mass basis, providing a breakdown of emissions across 14 regional gas networks:

National Grid Gas
- East of England
- East Midlands
- North London
- North West
- West Midlands

Northern Gas Networks
- North East
- Northern

Scotia Gas
- Scotland
- South East
- Southern

Wales and West Utilities
- South West
- Wales North
- Wales South

Phoenix Gas
- Northern Ireland

The UK GHG inventory estimates for 1B2biv are based on the aggregate of mass of gas leaked across all networks (low pressure mains and other losses), with the methane content of the natural gas based on compositional analysis from all of the gas network operators. The natural gas compositional data is summarised in **Annex 3**, presented within **Table A 3.2.19**.

The activity data reported in the CRF for these sources are the final UK annual gas demand data. These data are not used within the GHG inventory estimation method, but are presented to enable IEFs to be derived, to aid comparability of the UK estimates with those of other countries.

UK Gas Network Leakage Model
The UK gas network operators use a common industry leakage model to derive their annual estimates of gas leakage. The UK gas network leakage model was developed by British Gas and uses factors and assumptions on leakage rates for different types of gas mains and installations, based on measurements and surveys conducted in 1992 and 2002, with annual updates to maintain the representation of the UK gas network infrastructure (such as length and type of pipelines and other units) and reflect the rolling programme of network replacement. Historic data for the leakage from the low-pressure distribution network and other losses is based on studies from British Gas in the early 1990s (British Gas, 1993; Williams, 1993).

Natural Gas Compositional Data
The methane, CO_2 and NMVOC content of natural gas is presented in **Annex 3**, in **Table A 3.2.19**. The methane and NMVOC data were provided by contacts within British Gas Research for 1990-1996 and by UK Transco from 1997 to 2005 (Personal Communication: Dave Lander, 2008), and from the gas network operators from 2006 onwards (National Grid Gas, Scotia Gas, Northern Gas Networks, Wales & West, 2012). NMVOC content for 2001-

2003 has been estimated by interpolation due to a lack of data; CO_2 compositional data from 2004 onwards are derived from annual compositional analysis by gas network operators, whilst the 1990-2003 data have been extrapolated back from the 2004 figure. No gas composition data have been provided by Phoenix Gas and hence the UK average gas composition is assumed for Northern Ireland.

Each of the gas network operators obtain their compositional analysis from a central system of data logging from the automated sampling and analysis network that was operated previously under the Transco ownership, prior to the network being opened up to greater market competition. The inventory agency has direct contacts within the organisation (GL-Advantica) that manages the compositional data from across the UK gas network, and works directly with their gas analysis team to ensure that gas compositional data provided to the inventory agency by network operators is representative of the gas quality year-round, rather than a snap-shot from a limited number of analyses.

The calculation of the reported UK average gas composition is derived from the sum-product of the annual Local Distribution Zone (LDZ) compositional data and the estimated gas consumption through each of the LDZs, to provide an average gas composition for Great Britain which is then applied across the UK.

Northern Ireland Gas Network
The gas infrastructure in Northern Ireland is much newer than in the rest of the UK, as the gas pipeline (from Scotland) was only commissioned in 1999. Since then, the gas network has continued to develop across Northern Ireland. Annual estimates of gas leakage from 2005 onwards have been provided by the main gas operator (Phoenix Gas, 2012), and the data for 1999 to 2004 have been extrapolated back from the 2005 figure.

Other Gas leakage (1B2bv): Natural Gas Leakage at the Point of Use
During 2010, consultation with the gas network operators confirmed that the scope of the network leakage model did not include estimates of gas leakage downstream from the gas meter, i.e. at the point of use. Therefore, separate estimates are made in the UK GHGI for gas leakage at the point of use, using data on the numbers of gas appliances in the UK in the commercial and domestic sectors. These estimates are reported within 1B2bv, and in the CRF the activity data are presented for the total annual gas use by the domestic and commercial sectors from DUKES, in PJ, to aid comparability of the UK estimates with other country submissions.

Emissions from leakage at the point of use for gas boilers were included for the first time in the 2012 inventory submission; the UNFCCC ERT subsequently noted that pre-ignition losses for cooking and gas fires were not included. Despite the absence of an IPCC method for these sources, the UK inventory agency has now added new emission estimates for gas leaks at the point of use from domestic and commercial cooking appliances and from gas fires within the 1990-2011 UK GHG inventory.

The estimation method for natural gas leaks at point of use in the UK inventory includes:

Industrial Heating Boilers
Methane releases are assumed to be "**Not Occurring**" from these appliances, based on consultation with technical experts that advise the UK Government for the CHP QA scheme (Personal Communication: R Stewart, 2011). Larger boilers typically operate almost permanently once ignited (particularly if used for steam-raising) with little or no cycling from

on to off states. Furthermore, releases of un-burnt natural gas are strictly controlled in industrial locations for safety reasons.

Domestic Heating and Water Heating Boilers
The emissions of methane from the domestic heating and water heating boilers are estimated based on:

- an assumed average boiler size in the UK of 30kW
- a burn chamber size, natural gas flow rate taken from a typical combination boiler
- an air flow rate based on 25% excess oxygen in the combustion chamber when compared to stoichiometric ratio
- an equation for a mixed reactor ($1-e^x$) that when integrated will provide an estimate of the concentration of un-burnt air/fuel mixture released
- differing assumptions relating to the boiler yearly operation and cycling frequency, between heating and water heating applications

Using this model the emissions of the un-burnt mixture can be estimated for both the boiler when cycling during heating and water heating operation. The assumptions for the two operations are detailed below.

Domestic Heating
It is assumed that on average in the UK domestic properties have heating systems operating for half of the year and on average the heating is on for 5 hours per day. It is also assumed that during each hour that the boiler providing heating cycles on and off 4 times.

Domestic Water Heating
It is assumed that all UK domestic properties have hot water heating systems also have gas heated hot water. We have assumed operation every day of the year and on average heating is on for 4 hours per day. It is also assumed that during each hour that the boiler is providing hot water heating the boiler cycles on and off 5 times. This assumption is very uncertain as it is thought to depend on the boiler type, boiler condition and hot water usage in the property, and is thought to derive a conservative estimate.

Time series estimates for domestic heating and water heating gas leakage
The number of boilers from 1990 to 2011 is thought to have increased due to the increasing use of gas central heating for space heating, and the increase in the number of houses. It is assumed that pre-ignition gas loss in boilers installed in houses in 1990 were greater than in the current boilers installed, as technology has improved. However, the stock of domestic boilers (ca. 22 million in 2008) is assumed to be greater than that in 1990.

The inventory agency does not have access to detailed UK data for i) the stock of boilers in use over the time series; ii) the leakage from the boilers, and how this leakage changes with boiler technology. Therefore it has been assumed that the proportion of gas leaked (i.e. % of the total gas use) from domestic heating and water heating appliances per annum is steady across the time series, with the rationale that the sum of greater pre-ignition losses from fewer older-technology boilers in the early part of the time series will be roughly equivalent to the sum of lower pre ignition losses per unit from the greater number of newer-technology boilers in recent years.

Based on the model and assumptions outlined above, the emission of methane leaking from domestic boilers in the UK in 2008 has been estimated at 0.9 kt CH_4. Based on Energy Consumption in the UK (DECC, 2012) activity data for gas use in different appliance types,

this equates to a factor of 0.078 tCH_4 per Mth total gas use in domestic boilers. This factor has been applied to the ECUK activity data for domestic boiler appliances across the time series; across all years, the estimated annual emission is in the range 0.75-1.0 kt CH_4.

Domestic Cooking Appliances (manual and automatic ignition) and Gas Fires
Methane emission from pre-ignition losses of gas appliances used in domestic cooking and domestic gas fires are based on activity data from ECUK (DECC, 2012) which provides the full time series of gas use for heating, water heating and cooking in the domestic sector. The method then applies a series of assumptions regarding the operational cycles and delays to ignition, to derive a simple percentage non-combusted estimate for each gas appliance type.

The assumptions applied in the estimation method are:

- Gas fires use an estimated 2.5% of total gas used for space heating in the domestic sector, with the remainder used in (automatic ignition) boilers. This assumption is based on inventory agency expert judgement;
- Gas use in cooking hobs is estimated to be 73.6% of the total domestic gas use in cooking, with the remainder in gas ovens. This is based on data of average annual gas oven fuel use in kWh/yr and average domestic gas hob fuel use in kWh/yr, combined with data on UK stock of gas ovens and hobs, taken from a series of 2011 European Commission Eco-design studies (Bio IS / ERA Technology, 2011);
- For manual ignition devices, a conservative estimate of the delay prior to ignition of 2 seconds has been assumed (expert judgement), whilst the average operational cycle times for different types of appliance have been estimated at 900 seconds for a domestic hob (expert judgement) and 5400 seconds for a gas fire (EC Eco-design Lot 20 Task 5, gas stove base case, 2011);
- For automatic ignition appliances, a conservative estimate of the delay prior to ignition of 0.25 seconds has been assumed (expert judgement), whilst the average operational cycle times of domestic ovens has been estimated at 900 seconds (expert judgement);

In 2011, these assumptions lead to an overall estimate of 0.47 Mth of natural gas leaking from domestic cooking appliances and domestic gas fires, out of a total annual energy use in these appliances of 420 Mth. Converting to a mass-basis and then applying the annual natural gas compositional analysis from gas network operators leads to an estimate of methane leakage of 0.79 kt CH_4 in the UK in 2011. Across the time-series the estimates are all within the range 0.79-1.0 kt CH_4 leaked from domestic cooking and gas fires.

Commercial Gas Appliances: Catering and other uses
Methane emission from pre-ignition losses of gas appliances used in commercial catering and other uses are based on activity data from ECUK (DECC, 2012) which provides the full time series of gas use for catering and other uses in the commercial sector. The method then applies a series of assumptions regarding the operational cycles and delays to ignition, to derive a simple percentage non-combusted estimate for each gas appliance type.

The assumptions applied in the estimation method are:

- For commercial catering gas use, a conservative estimate of the delay prior to ignition of 0.5 seconds has been assumed (expert judgement, to reflect a mixture of hobs and oven use), whilst the average operational cycle has been estimated at 900 seconds (expert judgement);

- For other commercial gas appliances, assumed to be predominantly gas-fired boilers of automatic ignition design, a conservative estimate of the delay prior to ignition of 0.25 seconds has been assumed (expert judgement), whilst the average operational cycle time has been estimated at 1800 seconds (expert judgement);

In 2011, these assumptions lead to an overall estimate of 0.48 Mth of natural gas leaking from commercial gas appliances, out of a total annual energy use in these appliances of 2798 Mth. Converting to a mass-basis and then applying the annual natural gas compositional analysis from gas network operators leads to an estimate of methane leakage of 0.79 kt CH_4 in the UK in 2011. Across the time-series the estimates are all within the range 0.79-1.2 kt CH_4 leaked from commercial gas appliances.

An overview of the time series of gas leak at point of use estimates in the UK, together with overall gas use by economic sector and appliance type is presented below.

Note that these emission estimates are very uncertain due to the lack of detailed activity data, lack of appliance-specific leakage information and therefore the range of assumptions that have been made within the method; an estimated uncertainty of +/-50% has therefore been assigned to this source within the UK inventory uncertainty analysis.

Table 3-59 Overview of activity data and methane leakage estimates for Gas leakage at Point of Use, including cooking appliances and gas fired

Source / Appliance type	Units	1990	1995	2000	2005	2010	2011
Annual Gas Use							
Domestic gas fires	ktoe	462	520	621	650	673	467
Domestic manual ignition hobs / cookers	ktoe	590	530	511	496	444	437
Domestic auto-ignition hobs / cookers	ktoe	211	190	183	177	159	156
Domestic auto-ignition space and water heating	ktoe	24,572	26,796	30,491	31,512	32,223	24,130
Service sector catering (ovens and hobs)	ktoe	586	750	760	762	605	521
Other service sector appliances (boilers)	ktoe	6656	8520	9830	9302	7544	6529
Methane Leakage							
Domestic cooking and gas fires	$ktCH_4$	1.02	0.94	0.94	0.92	0.85	0.79
Domestic boilers and water heating	$ktCH_4$	0.76	0.83	0.94	0.98	1.00	0.75
Service sector (all sources)	$ktCH_4$	0.83	1.06	1.18	1.14	0.92	0.79
Total	**$ktCH_4$**	**2.61**	**2.83**	**3.07**	**3.04**	**2.76**	**2.33**

3.3.2.3 Uncertainties and Time Series Consistency

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and fuel type.

The emission estimates for the offshore industry are based on the EEMS dataset for 1998-2011, whilst emission estimates for 1990-1997 are based on trade association data (UKOOA 2005) to update earlier industry studies (UKOOA 1998) that had used production data as a basis for generating sector-wide estimates from 1990. The EEMS dataset (DECC, 2012) provides a consistent time-series of emission estimates for many facilities and sources, but since 2010 the reporting by onshore terminals is voluntary and the completeness of the dataset is variable for recent years. Furthermore, whilst the EEMS data quality appears to be improving over recent years, the completeness of EEMS data for specific facilities and sources is still subject to uncertainty; reporting gaps appear to be systematic for some facilities, such as frequent non-reporting of oil loading / unloading emissions at some terminals. The Inventory Agency continues to work with the regulatory agency, DECC, in the continued development of emission estimates from this sector, and there is a review of the EEMS system which began in late 2012 and is due to be completed during 2013.

The emission estimates from refineries, the gas supply network and from petrol distribution are all derived based on consistent methods across the time series using industry standard methods and a UK-specific gas network model. Uncertainties arise primarily from the use of emission factors for different process designs and delivery systems, especially in the refinery storage, transfer and petrol distribution systems.

Uncertainties in the emission estimates from leakage from the gas transmission and distribution network stem predominantly from the assumptions within the industry model that derives mass leakage estimates based on input data such as network pipe replacement (plastic replacing old metal pipelines) and activities/incidents at Above Ground Installations; for these sources the methane content of the gas released is known to a high degree of accuracy, but the mass emitted is based on industry calculations.

As noted in the section above, the uncertainties for the estimates of gas leakage at point of use are high due to the lack of source data, an IPCC method and the need to use a series of assumptions and expert judgement to estimate the leakage from different gas appliance types. The inventory agency considers that the assumptions provide a conservative estimate of gas leakage at point of use across the time series.

3.3.2.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. The DECC Offshore Inspectorate, in conjunction with Oil and Gas UK, provides emission estimation guidance for all operators to assist in the completion of EEMS and EU ETS returns to the UK environmental regulators, including the provision of appropriate default emission factors for specific activities, where installation-specific factors are not available.

The data gaps and inconsistencies evident within the latest (2011) data submission indicate that there is still some further improvement to the QA/QC of the source data by operators and regulators alike. Furthermore there are inconsistencies evident from oil and gas terminal submissions to different reporting mechanisms, which the inventory agency works with regulators and operators to reconcile in the compilation of the UK submission.

3.3.2.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 3-60** and emission factors in

Table 3-61 below. For information on the magnitude of recalculations to Source Category 1B2, see **Section 10**.

1B2aii Oil Production
1B2bii Gas Production / Processing
As part of the review of facility allocations and quality checks in the 2013 submission, the inventory agency identified that one offshore facility that was a gas-producing platform (East Brae) had previously been allocated to the oil sector. Therefore, in the latest submission, this allocation has been corrected and this has led to a small transfer of emissions from the upstream oil sector (1B2aii) to the upstream gas sector (1B2bii), but no change in the overall emissions. In 2010, the transfer amounted to 0.4 $ktCO_2e$ from oil to gas, with different amounts evident across other years in the time series.

Oil Loading Emissions: 1B2aiii Transport (offshore loading)
As part of the review of facility allocations and quality checks in the 2013 submission, the inventory agency identified that one offshore facility (Donan FPSO Global Producer III) which is a Floating Production and Storage vessel had failed to submit an EEMS report for 2010 for emissions from oil loading, whereas other source estimates were evident (e.g. for own gas use). To improve completeness, the inventory agency has added an estimate of the activity and emissions from oil loading for that facility, based on the 2010:2009 gas use ratio and the 2009 oil loading emissions. In 2010 this recalculation added 0.3 $ktCO_2e$.

Flaring: Oil (1B2ci) and Gas (1B2cii)
Emissions from flaring in 2010 across oil and gas sites were revised upwards by a total of 36.8 $ktCO_2e$ due to new estimates for one offshore facility (Douglas Platform) and one oil terminal (Sullom Voe). These revisions were due to (i) access to the EU ETS dataset for all offshore sites helping to identify that the Douglas platform had under-reported flaring emissions to EEMS in 2010, and (ii) review of IPPC reported data for the (two) regulated facilities at Sullom Voe – the terminal and the boiler plant – and correction of flaring data previously reported for 2010. In addition to these new estimates, a re-allocation of flaring emissions (from oil sector to gas sector) was implemented. This is due to the correction in allocation of the East Brae production platform, as outlined above in the oil / gas production recalculation text. The re-allocation of East Brae has impacted the estimates across the time series, but has led to no overall changes in "oil plus gas" flaring in the inventory, merely in the allocation between 1B2ci and 1B2cii.

1B2biii Transmission: High pressure gas transmission network leakage
1B2biv Distribution: Low pressure gas distribution network leakage.
For the first time in the 2013 submission, the methane emissions from the downstream natural gas network leakage is reported at a greater level of detail, with separate estimates derived for the high pressure transmission network and the low pressure distribution network. This revision to allocation in itself has not led to any changes in UK emissions data.

However, in addition to the separate reporting of the transmission network emissions, consultation with the gas network operators also led to a revision in the estimates for the leakage from the UK distribution gas network from 1992 to 2003.

Through consultation with experts at National Grid Gas in the latest compilation cycle, the inventory agency learned that the emission estimates from the two surveys (1992 and 2002) were integrated to the network leakage model, and that was the reason for a step-change in leakage estimates that had previously been reported in the UK GHG inventory submission between 2002 and 2003. The impact of the 2002 survey on the underlying analysis in the

leakage model led to much lower emission estimates for 2003; in the 2012 submission, the time series showed a 34% reduction in emissions between 2002 and 2003, as the data from the 2002 survey (which indicated much lower leakage rates than previous work) was included for the first time in the estimates for 2003 (and onwards). This step-change indicated a misleading time series of emissions between 1992 and 2002, and hence the data for 1992 to 2003 has been revised in this submission, using linear interpolation, to present a more realistic gas leakage time series between the two detailed industry surveys. UK gas network leakage experts noted that this revised time series is more representative of UK network replenishment during the 1990s and still is likely to generate conservative emission estimates for 1993-2002 as the network replacement programme addressed the oldest, highest leaking sections of the network first, and hence the linear interpolation is expected to under-estimate leakage reductions in the earlier years (Personal communication, NGG, 2012).

Other Gas leakage (1B2bv): Natural Gas Leakage at the Point of Use

As outlined in the methodology section above, in the latest submission new estimates of leakage at the point of use from domestic cooking appliances, gas fires and commercial cooking appliances have all been included in the UK inventory. This has led to higher activity data and emissions across the time series, and was implemented to improve completeness of UK inventory reporting, in response to UNFCCC review team recommendations at the 2012 in-country review.

Table 3-60 1B2 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
1B2b	Gas leakage	Natural Gas (transmission leakage)	NA	NA	10.8	8.9	kt	Improved transparency in reporting of emissions from the gas supply network in the UK, with new separate estimates of leakage from the gas transmission system (1B2biii), which previously was reported with distribution leakage in 1B2biv.No overall change to emission estimates for 1990 or 2010.
	Gas leakage	Natural gas supply (distribution leakage)	449.1	244.6	438.3	233.8	kt	
	Gas leakage	Natural Gas (leakage at point of use)	10251	13294	13125	16528	kt	Improved completeness. Emission estimates included in this submission for the first time, for leakage at point of use of gas in domestic gas fires and cooking appliances and in service sector gas appliances.
1B2cii	Upstream Oil Production - flaring	Non-fuel combustion	2,626,921	1,325,555	2,626,921	1,317,083	kt	Improved completeness, consistency and transparency. Correction to allocation of one site previously allocated to the oil sector, which is a gas producing facility. Also two oil production sites have revised estimates for 2010 due to (i) access to detailed EU ETS data for an offshore rig, (ii) source allocation revision for one oil terminal, based on IPPC reported data.
	Upstream Gas Production - flaring	Non-fuel combustion	110,757	172,696	110,757	193,793	kt	Improved time series consistency, transparency. Correction to allocation of one site previously allocated to the oil sector, which is a gas-producing facility.

Table 3-61 1B2 Recalculations to Emission Factors since the previous submission

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
1B2a	Upstream Oil Production - process emissions	CH4	Non-fuel combustion	10.3	2.55	10.3	2.53	kt (total emissions as reported)	Improved transparency. Correction of allocation of one site previously allocated to the oil sector, which is a gas-producing facility. No overall change in "oil plus gas" process emission estimates for 2010.
1B2b	Gas leakage	CH4	Natural Gas (leakage at point of use)	0.00009	0.00007	0.00020	0.00017	kt / Mt fuel consumed	Improved completeness. Higher emission factor across the time series due to inclusion of new estimates of leakage at point of use of gas in domestic and commercial cooking appliances.
		Carbon	Natural Gas (transmission leakage)	NA	NA	0.01	0.01	kt / Mt fuel consumed	Improved transparency. Emissions for leakage from the gas transmission system for the first time reported separately from gas distribution network, hence new IEFs reported across the time series.
		CH4	Natural Gas (transmission leakage)	NA	NA	0.84	0.80	kt / Mt fuel consumed	
	Upstream Gas Production - process emissions	CH4	Non-fuel combustion	21.81	2.32	21.81	2.34	kt (total emissions as reported)	Improved transparency. Correction of allocation of one site previously allocated to the oil sector, which is a gas-producing facility. No overall change in "oil plus gas" process emission estimates for 2010.

3.3.2.6 Source Specific Planned Improvements

During 2012-2013, the DECC Offshore Inspectorate is conducting a review of the EEMS reporting system for upstream oil and gas facilities, and it is anticipated that the reporting guidance and online system of templates for different source estimates will be reviewed and updated. The inventory agency will review any subsequent revisions to source estimates for all emission sources reported via EEMS.

Emission factors and activity data will be kept under review. The UK improvement programme is summarised in **Section 1.2.2.5.**

3.4 GENERAL COMMENTS ON QA/QC

3.4.1 DECC Energy Balance Data

DECC provides the majority of the energy statistics required for compilation of the NAEI and the GHGI. These statistics are obtained from the DECC publication – *The Digest of UK Energy Statistics* – which is produced in accordance with QA/QC requirements stipulated within the UK Government's – *National Statistics Code of Practice (ONS, 2002)* – and as such is subject to regular QA audits and reviews.

DECC include a number of steps to ensure the energy statistics are reliable. At an aggregate level, the energy balances are the key quality check with large statistical differences used to highlight areas for further investigation. Prior to this, DECC tries to ensure that individual returns are as accurate as possible. A two-stage process is used to achieve this. Initially the latest data returns are compared with those from previous months or quarters to highlight any anomalies. Where data are seasonal, comparison is also made with corresponding data for the same month or quarter in the previous year. DECC also uses an energy balance approach to verify that individual returns are sensible. Any queries are followed up with the reporting companies. DECC depends on data from a range of companies, and work closely with these reporting companies to ensure returns are completed as accurately as possible and in good time for the annual publications of statistics.

The data collection system used by DECC to collect and calculate sector-specific estimates of the use of petroleum-based fuels has been changed, and since January 2005 a new electronic system of reporting has been introduced. This development should lead to more consistent returns from petroleum industries, reducing misallocations and transcription errors that may have occurred under the previous paper-based system. Improvements are evident in DUKES 2006 onwards.

3.4.2 Industrial Point-Source Emissions Data

Where emissions data are provided by plant operators to the Environment Agency's Pollution Inventory and then used in the UK's GHG emission inventory, the data is subject to audit and review within the Agency's QA procedures.

The operator emission estimates are initially checked & verified locally by their main regulatory contact (Site Inspector), and then passed to a central Pollution Inventory team where further checks are conducted prior to publication. Specific checking procedures include: benchmarking across sectors, time-series consistency checks, checks on estimation methodologies and the use and applicability of emission factors used within calculations.

Sector-specific guidance regarding estimation of annual emissions by plant operators are under development by the Environment Agency. A rolling programme of guidance publication for different sectors has now been completed, and it is anticipated that this will lead to a gradual improvement of the consistency and accuracy of operator returns to the Pollution Inventory. The development of the SEPA and NI DoE reporting systems is anticipated to adopt these QA/QC mechanisms.

3.5 GENERAL COMMENTS ON ENERGY SECTOR TIME SERIES CONSISTENCY

The UK GHG inventory seeks to ensure time series consistency of its emission estimates. In general, the time series consistency of emissions will depend on:

- Consistency in the techniques used to compile activity data;
- Correct choice of source and fuel specific emission factors for each year of the inventory; and
- Consistency in the techniques used to estimate emissions from the activity data and emission factors.

Much of the core activity data for the sources reported in CRF sector 1 (Energy) is derived from the DECC publication the Digest of UK Energy Statistics. This is a long running publication and the compilers of the activity data for DUKES strive to use consistent methods to produce the activity data. This helps to ensure good time series consistency. Revisions of activity data may be made up to two years behind the latest reported year, but such revisions are clearly noted in DUKES and are incorporated into the GHG inventory when the inventory is updated each year. Where activity data other than that presented in DUKES are required for a source category, we have made quantitative and qualitative comments about the quality of the time series if possible.

The emission factors used are typically fuel and source-specific, and any comments on the time series consistency of the emission factors are made in the sections on uncertainties and time-series consistency in this chapter. Comments are restricted to the emission factors of the direct greenhouse gases.

In nearly all cases in the UK GHGI, a single method is used to estimate a time series of emissions from a specific source category. The technique of splicing two or more methods is rarely used. If a more sophisticated method is used to replace a simpler one, the entire time series of emissions is updated using the new method. Occasionally, there are insufficient data to produce a complete time series of emissions from the chosen method. Here, extrapolations and interpolations, use of surrogate data, and use of constant estimates of emission factors or activity data may be used to provide a complete time series.

The same options can be used when splicing methodologies, and in addition, it may also be necessary to overlap methodologies (Rypdal *et al.,* 2000).

4 Industrial Processes (CRF Sector 2)

4.1 OVERVIEW OF SECTOR

IPCC Categories Included	2A: Mineral Products 2B: Chemical Industry 2C: Metal Production 2D: Other Production 2E: Production of Halocarbons and SF_6 2F: Consumption of Halocarbons and SF_6
Gases Reported	CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NO_x, CO, NMVOC, SO_2
Key Categories (Trends)	Nitric Acid Production – N_2O
Key Categories (Level)	Industrial Processes – HFCs Nitric Acid Production – N_2O
Key Categories (Qualitative)	2A1 Cement Production – CO_2
Overseas Territories and Crown Dependencies Reporting	2A-2E are reported as not occurring. Estimates for use of F-gases based on scaled UK estimates are reported under 2F
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	Revised estimates of activity data for lime production. Revision to the process:combustion emissions split for ammonia production for recent years.

The industrial processes sector (IPCC Sector 2) contributes 5% to total greenhouse gas emissions. Emissions from this sector include non-energy related emissions from mineral products, chemical industry and metal production as well as emissions of F-gases. Since 1990, this category has seen a 51%decline in emissions, mostly due to changes in the emissions from the chemical production and metal processing industries. The step-change in emissions between 1998 and 1999 evident in **Figure 4-2** is due predominantly to the fitting of nitrous oxide abatement equipment at the UK's only adipic acid production plant (this plant has snice closed).

Table 4-1 gives details of the numbers of industrial plant relevant to this section over the time series.

Table 4-1 Number of industrial processes in the UK by type

Year	Cement	Lime – merchant[a]	Lime – captive[a]	Power stations with FGD	Glass-Works[b]	Fletton brick works	Ammonia
1990	23[c]	11[c]	12	0	33[c]	8	4
1995	23	9	11	1	33[c]	5	4
2000	21	9	11	2	34	3	4
2005	16	9	8	5	32	3	4
2006	16	9	8	5	30	3	4
2007	15	9	8	5	28	3	4
2008	15	9	8	7	26	3	3
2009	13	9	6	8	25	3	3
2010	12	9	6	8	25	2	3
2011	12	9	6	8	25	1	3
Year	Nitric acid	Adipic acid	Steel-works	Electric arc furnaces	Primary aluminium	Other non-ferrous[d]	
1990	8	1	4	20	4	5	
1995	6	1	4	20	4	4	
2000	6	1	4	19	4	3	
2005	4	1	3	12	3	2	
2006	4	1	3	11	3	2	
2007	4	1	3	10	3	2	
2008	4	1	3	8	3	2	
2009	2	1	3	7	3	2	
2010	2	0	2	7	2	2	
2011	2	0	2	7	2	2	

[a] merchant refers to site selling lime and emitting CO_2, captive refers to sites using lime and CO_2 in-situ so no emissions result.

[b] excludes very small glassworks producing lead crystal glass, frits etc.

[c] approximate figures only

[d] large-scale primary production or secondary refining operations only

The figures in Table 4.1 show that the numbers of industrial processes in the UK have been declining since 1990. While this is partly due to the closure of some smaller sites, perhaps with growth in capacity at remaining sites, it is predominantly a reflection of decreasing production of many industrial materials in the UK. A large number of closures in the period 2007-2009 were due to decreased demand for many products as a result of the general economic situation in the UK and elsewhere, with falling demand for steel, cement, bricks and aluminium, for example, leading to plant closures.

Figure 4-1 Breakdown of total GHG emissions in Industrial Processes sector

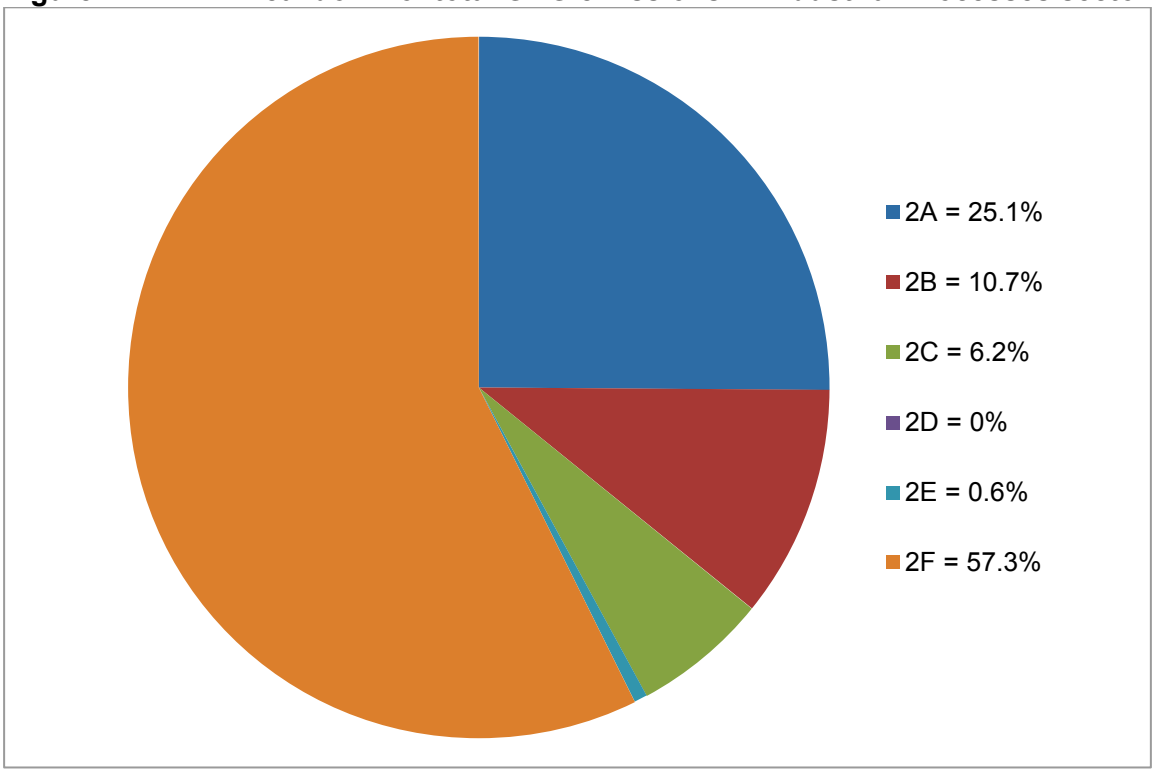
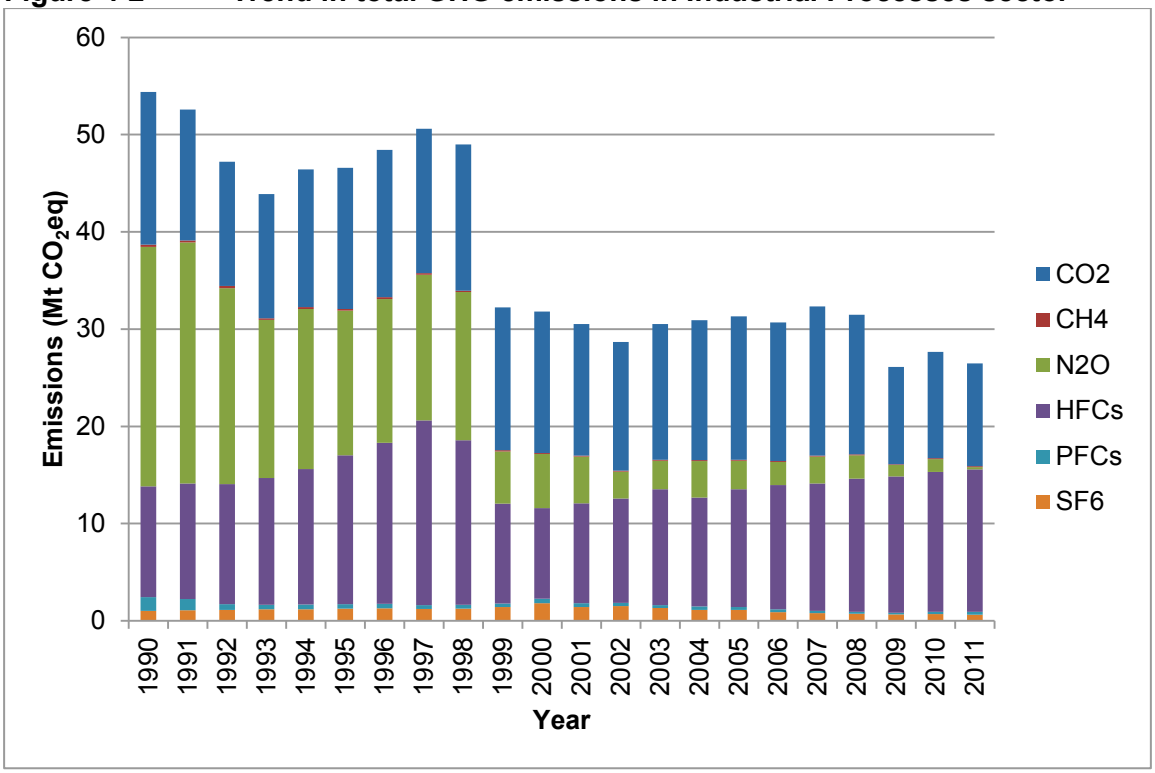


Figure 4-2 Trend in total GHG emissions in Industrial Processes sector



4.2 SOURCE CATEGORY 2A1 – CEMENT PRODUCTION

4.2.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2A1: Cement (Decarbonising)	T2	CS
Gases Reported	CO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	Cement (Decarbonising)		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Emissions of CO_2 from fuel combustion in cement kilns are reported under CRF source category 1A2f, whilst emissions from calcination of non-fuel feedstock to cement kilns are reported under category 2A1.

Fuel combustion also gives rise to emissions of NO_x and N_2O which are reported under 1A2f. Finally, emissions of methane, NMVOC, SO_2 and CO also occur, both due to fuel combustion but also due to the evaporation of organic or sulphurous components present in the raw materials. The current GHGI methodology for estimating emissions of these pollutants does not allow emissions from fuels and emissions from raw materials to be quantified separately and so all emissions of these four pollutants are reported under 1A2f.

The UK had 12 sites producing cement clinker during 2011.

4.2.2 Methodological Issues

The methodology used for estimating CO_2 emissions from calcination is to use data provided by the Mineral Products Association (2012), which in turn is based on data generated by UK cement clinker producers for the purposes of reporting to the EU Emission Trading Scheme. The data are available for 2005 to 2011 only, and so the emission factor value for 2005 has been applied to earlier years as well.

As part of the data quality checking routine for the sector, we compare emissions reported by the trade association to the aggregated installation specific data from the EU ETS. The EU ETS data explicitly includes emissions from all sources including cement kiln dust. Therefore this quality check ensures that there is complete coverage of all emissions from this sector.

Emission factors and activity data for the production of cement are commercially sensitive and therefore confidential. Change in cement production over the time series is the main

driver of the trend in emissions. Emission factors change only slightly from year to year, and so the trend in emissions to a large extent mirrors the trend in cement clinker production.

4.2.3 Uncertainties and Time Series Consistency

Emissions for 2005-2011 are estimated from the annual UK production of clinker and the emission factors provided by the Mineral Products Association. The time-series consistency of these data is very good due to the continuity in data provision by the Mineral Products Association. This organisation has also provided the clinker production estimates back to 1990, which are combined with the 2005 emission factor to generate the 1990-2004 emission estimates.

The activity data show a peak production of clinker in 1990, followed by a sharp decline by 1992/1993 (production in 1992 was just 75% of the figure in 1990). Following this slump, production increased again up until 1998, before declining again. Since 2007, production has fallen very sharply, with production in 2009 reaching its lowest point in the time series.

The initial large drop in clinker production over the period 1990-1993 can be explained by a sharp drop in construction activity and hence a decline in the need for cement (confirmed by statistics available for the construction industry). The less pronounced downward trend in production over the period 1994-2007 may, in part, be due to increased use of slag cement, the production of which is likely to have risen sharply over the same period. The sharp decrease in production since 2007 is linked to the recession, which has caused a decline in construction and therefore demand for cement. A number of cement kilns were closed or mothballed during 2008 and 2009.

The emission factors used for cement for the period 2005-2011 are relatively constant, with only small year on year changes. The trend in emissions therefore largely reflects the trend in activity data.

4.2.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Emissions reported to the inventory agency by the Mineral Products Association have been cross checked with plant specific data reported in the EU ETS to ensure complete coverage of all emissions.

4.2.5 Source Specific Recalculations

No recalculations have been made in this category.

4.2.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.3 SOURCE CATEGORY 2A2 – LIME PRODUCTION

4.3.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2A2: Lime Production (Decarbonising)	T2	CS
Gases Reported	CO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Revision of estimates for activity data.		

Lime (CaO) is manufactured by the calcination of limestone ($CaCO_3$) and dolomite ($CaCO_3MgCO_3$) in kilns fired by coal, coke or gas. The calcination results in the evolution of carbon dioxide. However, for the inventory it is necessary to distinguish between processes where lime is produced for use off-site and where carbon dioxide is emitted to atmosphere, and those processes where lime is produced so that the carbon dioxide and lime can be used on-site in the process. In these latter processes, which include sugar refining and the production of sodium carbonate using the Solvay process, most of the carbon dioxide is not emitted to atmosphere.

Lime was produced at 15 UK sites during 2011. Two of these produce lime for use on-site in the Solvay process and four produce lime for use on-site in sugar manufacturing.

4.3.2 Methodological Issues

The UK previously based estimation of lime production emissions on limestone and dolomite consumption data, which were readily available (British Geological Survey, 2012). However, site-specific data from EU ETS and other sources have suggested a much higher production of lime in recent years, and so the activity data used in the UK inventory have now been revised to take into account this alternative information. The EU ETS data consist of CO_2 emission estimates and activity data from 2005 onwards. The activity data take various forms e.g. feedstock or product, depending upon site, and so the emissions data have been adopted, with the lime activity data then being back-calculated using a default emission factor of 121.5 t carbon/ kt limestone or dolomite. This emission factor is derived by assuming that 85% of UK lime production is from limestone and the remaining 15% is from dolomite (based on a recommendation from the EU's UNFCCC review). For limestone, an emission factor of 120 t carbon/kt limestone is then assumed, based on the stoichiometry of the chemical reaction, and for dolomite, the corresponding emission factor of 130 t carbon/kt dolomite is used. The calculated activity data excludes carbonates calcined in the chemical

industry since this is all used in the Solvay process, which does not release CO_2. The calcination of limestone in the sugar industry is also excluded for the same reason.

Prior to 2005 there are no EU ETS data, and data are also missing for 2005-2006 for some lime kilns because of UK exemptions from the EU ETS for some sites in those years. So, between 1994 and 2004, CO_2 emission estimates for lime production are based on emissions data published in the Pollution Inventory (PI). The PI data are mostly for total CO_2 i.e. include emissions from both decarbonisation and fuel combustion, but estimates of the CO_2 from decarbonisation only are made using EU ETS data and PI data for 2006-2008, both of which give fuel combustion emissions separately from decarbonisation. For the period 1994-1997, there is less reporting of CO_2 in the PI and so site-specific CO_2 emissions are estimated based on other site-specific data such as emissions data for particulate matter from those sites in the relevant years. The PI-based data, like the EU ETS data, suggest that the BGS activity data, previously used in the UK inventory, are too low. The discrepancy between the two data sets did seem to change over time, with a relatively small difference in the seven year period 1994-2000, compared with much larger differences from 2001 onwards. In that 1994-2000 period, the emissions data from the PI were on average 8% higher than emissions based on BGS data and the default emission factor. We have no PI data for the period 1990-1993 so BGS activity data are the only data available to calculate emissions. Because emissions estimates based on BGS data are consistently lower than emissions from PI and EU ETS sources for the period from 1994 onwards, we have assumed that BGS data for 1990-1993 would also underestimate emissions and have therefore applied a 'correction' factor of 1.08 to the BGS data for those years. The methods used for each part of the time series are summarised below.

Table 4-2 Methods used to estimate emissions from this category

Period	Activity data	Emission factor, kt C / kt carbonate	Emission
1990-1993	BGS x 1.08	121.5	AD x EF
1994-1997	(back-calculated)	121.5	PI CO_2 + estimates extrapolated from later PI data on basis of other data such as emissions data for other pollutants
1998-2004	(back-calculated)	121.5	PI CO_2
2005-2006	(back-calculated)	121.5	EU ETS & PI CO_2
2007-2011	(back-calculated)	121.5	EU ETS

Emission factors for indirect gases from the production of lime are calculated from emissions reported in the PI in the case of CO and NOx, and for VOC based on literature factors**.**

4.3.3 Uncertainties and Time Series Consistency

Uncertainty in the emission estimates for this source is judged to be low, although varying over the time series somewhat. EU ETS data are used for the period from 2005 onwards and exclusively so, from 2008 onwards, and the later part of the time series is therefore judged to be high quality. Uncertainty is thought higher though for the estimates before 2005, because of the need for assumptions to be made in deriving the estimates (for example, assumptions regarding the split between combustion and process emissions in the

PI data used between 1994 and 2004). The estimates exclude sites producing lime for use by the chemicals industry and sugar production, and this could conceivably lead lead to a small underestimate across the entire time series if not all CO_2 is consumed by the processes. EU ETS data for the sugar processes does not, however, provide any evidence that any of the CO_2 is emitted at those sites (the soda ash processes are not part of EU ETS at the moment)..

4.3.4 Source-specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Cross comparison of the BGS data with the EU ETS data as a means of verification has indicated a potential under report in the BGS data. This has led to a change in the methodology to ensure completeness of the inventory reporting.

4.3.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-3** below. For information on the magnitude of recalculations to Source Category 2A2, see **Section 10**.

Table 4-3 2A2 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission			Comment/Justification
			1990	2010	1990	2010	Units	
2A2	Lime production - decarbonising	Limestone	2.708	0.525	3.223	2.460	Mt	Activity data revised. Now consistent with ETS and PI emissions data.

4.3.6 Source Specific Planned Improvements

The inventory has been updated to replace the BGS data with information from the ETS and the Pollution Inventory. Further stakeholder consultation is proposed to ensure that the assumptions made are appropriate. In addition, investigation of potential emissions from the limestone use in the chemicals industry and sugar production is being considered.

4.4 SOURCE CATEGORY 2A3 – LIMESTONE & DOLOMITE USE

4.4.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2A3: Basic oxygen furnaces Sinter production Power Stations (FGD)	T2 T2 T2	CS CS D
Gases Reported	CO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Limestone and dolomite are added to sinter where they are calcined, the products subsequently acting as slag formers in blast furnaces. Some limestone or dolomite may be added directly to blast furnaces instead of being sintered first, but this practice is ignored for the GHGI with all additions and, therefore, emissions being assumed to be associated with the sinter strand instead. Dolomite is also an important addition as fluxing agents to basic oxygen furnaces and this is reported as a separate category under 2A3. Limestone and dolomite are also used as sources of CaO and MgO in the manufacture of soda-lime glasses and for the liming of soils by the agricultural sector. Glass industry emissions are, however, discussed in **Section 4.8,** while agricultural use is covered in **Chapter 6** of this report.

Use of limestone and dolomite in sinter production and basic oxygen furnaces result in the evolution of carbon dioxide, which is emitted to atmosphere. Limestone is also used in flue-gas desulphurisation (FGD) plant used to abate SO_2 emissions from combustion processes. The limestone reacts with the SO_2 present in flue gases, being converted to gypsum, with CO_2 being evolved.

4.4.2 Methodological Issues

Data on the usage of limestone and dolomite for steel production are available from the Iron & Steel Statistics Bureau (2012). Corus UK Ltd has provided analytical data for the carbon content of limestone and dolomite used at their steelworks (Corus, 2005), and these have been used to generate emission factors of 111 t carbon/kt limestone and 123 t carbon/kt dolomite for sintering and basic oxygen furnaces.

Emissions are calculated using an emission factor of 69 t carbon/kt gypsum produced in the case of FGD processes. This factor is based on the stoichiometric relationship between gypsum and carbon dioxide formed in the FGD plant. Data on gypsum produced in FGD plant has previously been taken from the British Geological Survey (2012),, but these data are not always consistent with site-specific emissions data available from EU ETS, and so now a composite series of activity data is used with BGS data for 1994-2004, and EU ETS data for 2005-2011. BGS data for 2005 are in very good agreement with EU ETS data for that year, and so it has been assumed that BGS data for 1994-2004 are also comparable with the later EU ETS data.

4.4.3 Uncertainties and Time Series Consistency

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and fuel type.

Uncertainty in all of the emission factors and some of the activity data used for this source are judged to be low. Time-series consistency is also very good due to the continuity in data provision by the Iron & Steel Statistics Bureau. In the case of FGD plant, there is a change in methodology between 2004 and 2005 because of the availability of high quality EU ETS data from 2005 onwards, whereas previously BGS data have to be used. However, BGS and EU ETS-based emission estimates for 2005 are very close, and for 2006-2011 are within 8% of each other.

4.4.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

4.4.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-4** below. For information on the magnitude of recalculations to Source Category 2A3, see **Section 10**.

Table 4-4 2A3 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
2A3	Power stations - FGD	Gypsum produced	0	1404	0	1509	kt	Revision to AD for 2005 onwards to use EU ETS data since BGS data is occasionally incomplete and inconsistent with high quality EU ETS data.

4.4.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.5 SOURCE CATEGORY 2A4 – SODA ASH PRODUCTION & USE

Soda ash has been produced at two sites in the UK, both operating over the entire time period covered by the inventory. Emissions from fuels used at these sites will be included in 1A2c. Emissions are assumed not to occur from the process itself since the soda ash is manufactured using the Solvay process and not from Trona, and all carbon dioxide formed from calcination of the limestone used in the UK processes is assumed to be sequestered in the soda ash product.

Emissions from soda ash (sodium carbonate, Na_2CO_3) used in the manufacture of soda-lime glasses is reported under source category 2A7. Other uses of soda ash can also result in the emission of CO_2, including use in food and drink manufacture and pharmaceuticals, however the consumption of soda ash for these applications is small and emissions are not estimated.

4.6 SOURCE CATEGORY 2A5 – ASPHALT ROOFING

Emissions of CO_2 are not estimated from this source as there is no methodology available. Emissions from this source category are likely to be extremely small in relation to national emissions.

4.7 SOURCE CATEGORY 2A6 – ROAD PAVING WITH ASPHALT

4.7.1 Source Category Description

Emissions sources	2A6: Road Construction
Gases Reported	NMVOC
Key Categories (Trends)	None identified
Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements made

Bitumen is used in the preparation of road surfaces. Different types of surface dressing are used and some contain kerosene as well as bitumen, the kerosene being used to reduce the viscosity of the road dressing. The kerosene partially evaporates once the road dressing is laid and is emitted to atmosphere. Emissions of NMVOC are reported under 2A6.

4.7.2 Methodological Issues

Emissions of CO_2 are not estimated from this source, as there is no methodology available. Emissions from this source category are likely to be extremely small in relation to national emissions.

The inventory reports emissions of NMVOC from the use of bitumen emulsions, cut-back bitumens, and cut-back fluxes used in road construction using emission factors of 7, 87.5 and 700 kg NMVOC/ tonne for each component respectively (Refined Bitumen Association, 1990). These estimates are based on the assumption that only 70% of the kerosene is emitted, the remainder being fixed in the road material. Estimates of the usage of these surface dressings are based on a set of consumption data for one year only, provided by the Transport and Road Research Laboratory (1989) and are extrapolated to other years using data for annual bitumen consumption given in the Digest of UK Energy Statistics (DECC, 2012).

4.7.3 Uncertainties and Time Series Consistency

The estimates of NMVOC from road paving are quite uncertain, due particularly due the long-term extrapolation of a single set of consumption data. Emissions occur due only to the use of specialised bitumen products containing kerosene and it is unclear whether the extrapolation using consumption of bitumen for all applications will be reliable. An uncertainty analysis for indirect GHGs is not included in this report.

4.7.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

4.7.5 Source Specific Recalculations

No recalculations have been made in this category.

4.7.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.8 SOURCE CATEGORY 2A7 – OTHER MINERAL PRODUCTS

4.8.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2A7: Glass Production	T2	CS, D
	Brick Manufacture (Fletton)	T2	CS, D
	Glass (continuous filament glass fibre)	T2	CS, D
	Glass (glass wool)	T2	CS, D

Gases Reported	CO_2, CH_4, CO, NO_x, SO_2, VOC
Key Categories (Trends)	None identified
Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

Emissions from Fletton brickworks, glass manufacture, and manufacture of coated roadstone are reported under 2A7. Emissions from glass manufacture include those emissions of carbon dioxide that result from the use of limestone, dolomite and soda ash as sources of CaO, MgO and Na_2O respectively in soda-lime and other glasses.

Fletton bricks are manufactured in Southern England using the Lower Oxford Clay. This clay contains a high level of carbonaceous material which acts as a fuel during firing, leading to emissions of carbon dioxide, carbon monoxide, methane, and NMVOC. The clay also contains sulphurous material, which results in SO_2 emissions as well.

The UK is thought to have had 22 large sites making glass at the end of 2011, for the production of container glass (12 sites), flat glass (5 sites), , continuous filament glass fibre (1 site), or glass wool (4 sites). There are also 3 sites producing stone wool. Special and domestic glasses are no longer manufactured on a large scale in the UK, and production of lead glass, frits and ceramic fibres are only on a very small scale. Currently, it is assumed that limestone and dolomite are used in the production of container, flat, and special glass, and in glass wool. However, EU ETS returns suggest that small quantities of carbonates could also be used in rock wool manufacture so this part of the inventory will be reviewed for the next version.

As well as carbon dioxide emissions resulting from the decomposition of carbonate feedstocks, certain types of glass manufacture will give rise to emissions of other pollutants including NO_X, SO_2 and VOC. Emissions of NO_X and SO_2 can occur during melting due to the breakdown of nitrates and sulphates in the raw materials, while VOC emissions can occur from the use of coating materials for glass fibres. Both continuous filament glass fibre and glass/rock wool manufacture involve the attenuation of molten product into fine fibres, which are then cooled and coated with organic materials. Currently, we do not estimate emissions of NO_X and SO_2 from glass melting due to a lack of suitable data. Emissions are, however, expected to be relatively small.

Carbon dioxide emissions may also occur from the use of other materials in the glass and brick industries, for example other carbonates such as potassium and barium carbonate. Emissions are likely to be very small although some emissions data are available through EU ETS sources which may allow a time series of emission estimates to be generated in future.

Coated roadstone is produced at numerous sites. The stone is quarried, crushed and then coated with bitumen. Emissions of NMVOC from these processes are relatively trivial.
Nitrous oxide emissions from glass production, Fletton brick production and asphalt are not estimated since suitable methods or data have not been found. Emissions from these sources are, however, believed to be very small.

4.8.2 Methodological Issues

Methodologies are summarised in **Table 4-5**.

Table 4-5 Summary of Emission Estimation Methods for Source Categories in CRF Category 2A7

Source Category	Method	Activity Data	Emission Factors
Fletton bricks	UK model	Inventory Agency estimates, based on Government statistics on brick production	CO_2, CH_4: based on total site emissions reported by operator, after subtraction of an estimate of emissions from fuel combustion N_2O: Not occurring
Glass Production	AD x EF	Inventory Agency estimates, based on industry data	CO_2: based on carbon content of carbonates CH_4, N_2O: Not occurring

Emissions data for Fletton brickworks during recent years are available from the Pollution Inventory (Environment Agency, 2012). These data include emissions both from the burning of the carbonaceous and sulphurous material in the clay but also from the burning of coal and gas used as support fuel in the kilns. Emissions from the clay materials are derived by first estimating the likely emissions from coal and gas burnt in the brick kilns and then subtracting these estimates, which are included in source category 1A2f, from the emissions reported in the Pollution Inventory. The site that closed in 2008 burnt coal, whereas the other two sites in operation in recent years burn natural gas. This fuel is now, therefore, the only fossil fuel burnt by the Fletton brick industry. The Pollution Inventory emissions data are available back to 1998, although SO_2 emissions data extend back to 1993. Emissions prior to these years have therefore been derived by assuming that emission factors remain at the level calculated for 1998 (or 1993 in the case of SO_2).

Emissions from the use of carbonates in glass production are calculated using emission factors based on the stoichiometric relationship between carbon and the related carbonate i.e. 120 t carbon/kt limestone, 130 t carbon/kt dolomite, and 113 kt carbon/Mt soda ash. These factors assume that all of the carbon in the carbonates is released to atmosphere. The British Geological Survey has previously been the source of data on the consumption of limestone and dolomite by the glass industry. However, the data available for the last ten years are very incomplete and in the years before that show surprising year on year variations that do not fit well with estimates of glass production. An alternative approach is now used which takes a detailed, site by site survey of raw material usage, carried out in 2006 (GTS, 2008) as a starting point. The estimates of dolomite and limestone use by sector from this survey are extrapolated to all other years in the time series on the basis of glass production in each year. This glass industry survey did not cover the stone wool sector and so limestone and dolomite usage in that sector is not calculated.

Consumption of soda ash is estimated using an assumption that this is equal to 20% of the mass of soda-lime glass produced - a figure which is based on data provided by the glass industry (British Glass, 2001). Glass production data are available on an annual basis for container glass only (British Glass, 2011), and production of other types of glass has to be estimated based on data for a limited number of years (e.g. British Glass, 2001; EIPPCB, 2000), extrapolated to other years on the basis of estimated plant capacity. The glass production data are corrected for the amount of recycled glass (cullet) and the soda ash consumption is therefore estimated as 20% of the new glass melted and not total glass melted. The estimate of soda ash consumption is based on the production of container glass, flat glass and domestic glass only, since other glass sectors use different glass formulations such as borosilicate glass, and the emission factor used is applicable to soda-lime glasses only. EU ETS data suggests that there is some small use of limestone and dolomite at some sites involved in the manufacture of continuous filament glass fibre and glass wool and so, as with stone wool, the inventory methodology should be reviewed.

Table 4-6 gives summary details for the UK glass industry and the scope of estimates for CO_2 emissions from carbonate use.

Table 4-6 Background Information on the Estimation of Emissions from Carbonate Use in Glassmaking and Related Industries

Glass Sector	1990 production, kt	2011 production, kt	Estimates included for emissions from use of:		
			Limestone	Dolomite	Soda Ash
Container	1771	2311	Yes	Yes	Yes
Flat	875	810	Yes	Yes	Yes
Special	226	0	Yes	Yes	No
Domestic, including lead	76	<1	Yes	Yes	Yes
Continuous filament glass fibre	82	37	Yes	Yes	No
Glass wool	104	278	Yes	Yes	No
Stone wool	83	97	No	No	No
Ceramic fibres	14	14	No	No	No
Frits	13	7	No	No	No

Emissions of NMVOC from glass fibre and glass wool processes in recent years are available from the Pollution Inventory, although these do not include one glass wool producer located in Scotland. The Pollution Inventory data are used to calculate emission factors, based on estimates of glass production and emissions can then be calculated both to include all processes and, by extrapolation, to include other years.

Emissions of NMVOC during manufacture of coated roadstone are estimated using production data from TSO, 2009 and an emission factor of 8.73 g/t coated roadstone, which is the average of emission factors given by US EPA, 2007 for various types of batch roadstone coating plant.

4.8.3 Uncertainties and Time Series Consistency

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and fuel type.

In the case of limestone and dolomite use by the glass industry, the methodology is based on the extrapolation of highly accurate activity data for one year to all other years based on

estimates of glass production. Because the estimates of glass production are themselves quite uncertain, these activity data for the glass industry are more uncertain.
The calculation of soda ash consumption is subject to uncertainties linked to:

- Glass production data, which are themselves estimates subject to moderate uncertainty; and
- Estimate of the rate of soda ash production per tonne of glass, which is an approximate figure.

The emission factor is based on the stoichiometry of the chemical reaction undergone by the soda ash and will be accurate. The time-series required some interpolation of data from year to year.

Some small additional emissions may be occurring in the glass, brick, and related industries – dolomite and limestone used in rock wool production, soda ash used in continuous filament glass fibre and glass wool, and from the use of barium carbonate & potassium carbonate in glassmaking and brickmaking generally.

Estimates for Fletton bricks, carbon in particular, are sensitive to the assumptions made about supplementary fuel use and so the estimates could be improved were fuel consumption data available. The time-series involves some extrapolation of data using brick production estimates and this will introduce further uncertainty within the earlier part of the time series.

The emission estimates for the remaining sources are also subject to significant levels of uncertainty, however these are very minor sources of NMVOC emissions only, and are not considered further.

4.8.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

4.8.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-7** and emission factors in **Table 4-8** below. For information on the magnitude of recalculations to Source Category 2A7, see **Section 10**.

Table 4-7 2A7 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
2A7	Brick manufacture - Fletton	Fletton bricks	1833	518	1833	551	kt	Revisions to national statistics relating to brick manufacture
	Glass - general	Limestone	0.219	0.253	0.223	0.244	Mt	Updated activity data time series from British Glass
		Dolomite	0.201	0.233	0.232	0.213	Mt	Updated activity data time series from British Glass
		Soda ash	0.404	0.511	0.404	0.436	Mt	Updated activity data time series from British Glass

Table 4-8 2A7 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
2A7	Brick manufacture - Fletton	Carbon	Fletton bricks	0.027	0.051	0.027	0.047	kt / kt	Revisions to estimates of combustion/process split in reported emissions (due to revised estimates of brick production)
		CH4		0.001	0.001	0.001	0.000	kt / kt	Revisions to estimates of combustion/process split in reported emissions (due to revised estimates of brick production)

4.8.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.9 SOURCE CATEGORY 2B1 – AMMONIA PRODUCTION

4.9.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B1: Ammonia Feedstock	T1	CS
Gases Reported	CO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	CO_2 recovery is no longer subtracted from the emissions total for ammonia production. This is because it is not clear if the storage is permanent and to ensure compliance with the IPCC guidelines.		

Ammonia is typically produced using the Haber process, which starts with the steam reforming of natural gas to make hydrogen. The simplified reactions are:

$$CH_4 + H_2O \Leftrightarrow CO + 3H_2$$
$$CO + H_2O \Leftrightarrow CO_2 + H_2$$

The hydrogen is then reacted with nitrogen from air to form ammonia.

$$N_2 + 3H_2 \Leftrightarrow 2NH_3$$

If the by-products CO and CO_2 are not captured and used, then these are emitted to atmosphere. Ammonia plants can be integrated with methanol manufacture for greater efficiency, since some of the carbon oxides can be used to manufacture methanol:

$$CO + 2H_2 \Leftrightarrow CH_3OH$$

Over the time period covered by the UK greenhouse gas inventory, ammonia has been manufactured at four locations in the UK. CO_2 emissions are reported from three of those sites, because at the remaining site (Hull), the ammonia is produced with hydrogen supplied as a by-product from another chemical process operated on a neighbouring site. That other process reforms natural gas to produce CO_2 used in the manufacture of chemical feedstocks, and so the CO_2 is assumed stored. At one of the remaining three sites where CO_2 is

reported, some carbon from the steam reformer was, until 2001, exported for use in the manufacture of methanol. That carbon was still reported as emitted in line with IPCC Guidelines for ammonia production processes.

One ammonia plant sells CO_2 to the food industry and nuclear industry. Because this CO_2 is still ultimately emitted to atmosphere, it is included in the emissions reported here. This is considered more reliable than trying to identify carbon emissions at the point of final use since CO_2 will also be emitted from other processes such as fermentation.

Methane and nitrous oxide emissions are reported as not estimated. Manufacturers do not report emissions from these pollutants and they are therefore assumed to be negligible.

4.9.2 Methodological Issues

Emissions from ammonia production are reported under two inventory source categories. The first category is reserved for emissions of CO_2 from natural gas used as a feedstock in the ammonia process. The second category includes emissions of CO_2 and other pollutants from the combustion of natural gas to produce the heat required by the reforming process used as part of those ammonia processes. Because this second category involves the use of gas for energy production, emissions are reported under 1A2c and are not discussed further.

Emissions of CO_2 from feedstock use of natural gas are calculated by combining reported data on CO_2 produced, emitted and sold by the various ammonia processes. Where data are not available, they have been calculated from other data such as plant capacity or natural gas consumption. The ammonia plant utilising hydrogen by-product from chemicals manufacture does not need to be included since there are no process emissions of CO_2.

Table 4-9 summarises the details of the UK ammonia plants and **Table 4-10** gives details of production and emissions etc. by the sector.

Table 4-9 Details of UK ammonia plants

Plant	Feedstock	Carbon emissions	Notes
Billingham	Natural gas	Yes	Some production of methanol using by-product carbon until 2001
Severnside	Natural gas	Yes	Closed in 2007
Ince	Natural gas	Yes	
Hull	Hydrogen	No	

Table 4-10 UK ammonia production and emission factors

Year	Ammonia production, ktonnes		Gas for feedstock, TJ	CO_2 emitted, ktonnes	CO_2 emission factor		
	Total	Excluding Hull	Ammonia plant		t / TJ	t / t NH_3 *(all UK production plant)**	t / t NH_3 *(excluding Hull plant production)*
1990	1328	1128	28413	1431	50.37	1.08	1.27
1995	1388	1145	28741	1462	50.88	1.05	1.28
2000	1213	986	26957	1382	51.28	1.14	1.40
2005	1172	945	23660	1200	50.73	1.02	1.27
2006	949	722	17752	901	50.73	0.95	1.25
2007	1251	1024	24301	1235	50.81	0.99	1.21
2008	1082	855	19885	1019	51.24	0.94	1.19
2009	889	662	14980	767	51.22	0.86	1.16
2010	1084	857	18951	969	51.15	0.89	1.13
2011	800	573	12592	643	51.03	0.80	1.12

*As reported within the CRF table 2(I).A-Gs1

CRF table 2(I).A-Gs1 presents the ammonia production data for all UK sites (including Hull where there are no CO_2 emissions). In order to aid transparency and comparability of the country-specific IEFs for this source, in the table above we also provide the time series of CO_2 emission factors on an energy basis (t/TJ) which shows close consistency across all years, and also an emission factor per tonne of ammonia production for the three sites where there are CO_2 emissions (the right hand column) which is a higher IEF than the UK aggregate including the Hull plant production that is presented in the CRF.

4.9.3 Uncertainties and Time Series Consistency

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and fuel type. The uncertainty associated with this source is low, since the carbon content of natural gas is well known and plant specific data are received from the operators annually.

A consistent time series of activity data has been reported from the manufacturers of ammonia, and this results in good time series consistency of emissions. For 2001 to 2006, no new ammonia production data were received from one plant operator. Production estimates from 2000 and annual plant emissions data from the Environment Agency Pollution Inventory have been used to estimate production & emissions from this plant in 2001-2006.

4.9.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6** and the source emissions data from plant operators is subject to the QA/QC procedures of the Environment Agency's Pollution Inventory.

4.9.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-11** and emission factors in **Table 4-12** below. For information on the magnitude of recalculations to Source Category 2B1, see **Section 10**.

Table 4-11 2B1 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
2B1	Ammonia production - feedstock use of gas	Natural gas	470	278	470	276	Mth fuel consumed	Correction to split between process and fuel use emissions for ammonia production based on operator data. Reallocation between 2B1 and 1A2c.

Table 4-12 2B1 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
2B1	Ammonia production - feedstock use of gas	Carbon	Natural gas	0.830	0.960	0.830	0.957	kt / kt	Use of updated data from process operators

4.9.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.10 SOURCE CATEGORY 2B2 – NITRIC ACID PRODUCTION

4.10.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B2: Nitric Acid Production	CS	CS
Gases Reported	N_2O, NO_x		
Key Categories (Trends)	None identified		
Key Categories (Level)	Nitric Acid Production – N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Nitric acid is produced by the catalytic oxidation of ammonia:

$$4NH_3 + 5O_2 \Rightarrow 4NO + 6H_2O$$
$$2NO + O_2 \Leftrightarrow 2NO_2$$
$$3NO_2 + H_2O \Leftrightarrow 2HNO_3 + NO$$

Nitrous oxide is also formed by oxidation of ammonia:

$$4NH_3 + 3O_2 \Rightarrow 2N_2O + 6H_2O$$

Nitrous oxide is emitted from the process as well as a small percentage of the NO_x. At the end of 2011, nitric acid was being manufactured at 2 UK sites with a total of 4 production plants. At one site, the nitric acid production plant has had NO_x/N_2O abatement fitted to all units since commissioning (pre-1990), whilst at the other UK production site, all three production lines have had nitrous oxide abatement retrospectively fitted during 2011 Quarter 1. This has led to a notable reduction in the UK IEF for nitrous oxide emissions from nitric acid production in the UK between 2010 and 2011 (see Table 4-13 below).

4.10.2 Methodological Issues

Across the 1990-2009 time-series, the availability of emissions and production data for UK Nitric Acid (NA) plant is inconsistent, and hence a range of methodologies have had to be used to provide estimates and derive emission factors for this sector. Where possible, emission estimates are based on site-specific data provided by process operators.

Over the period covered by the UK inventory, there have been nitric acid plants operating in England, Northern Ireland, and Scotland, although all production in Scotland ceased in the early 1990s. For plant in England, emissions data from plant operators are available for all sites from 1998 onwards from the EA's Pollution Inventory. For the single plant (now closed) in Northern Ireland, emissions data from plant operators became available from 2001. There is no site-specific data for any Scottish plants.

Site-specific production estimates are largely based on production capacity reported directly by the plant operators. This approach may overestimate actual production. No data are available for three sites operating between 1990 and 1993, and production at these sites is calculated based on the difference between estimates of total production and the sum of production at the other sites.

Emission estimates for N_2O are derived for each NA site using:

a) Emissions data provided by the process operators directly or via the Pollution Inventory (1998 onwards for plant in England, 2001 onwards for plant in N Ireland);
b) Site-specific emission factors derived from reported emissions data for the same site for another year (1990-1997 for some plant in England, 1994-1997 for other plant in England, 1990-2000 for plant in N Ireland); and
c) A default emission factor of 6 kt N_2O /Mt 100% acid produced in cases where no emissions data are available for the site (some sites in England, Scotland, 1990-1993). This default factor is the average of the range quoted in IPCC Guidelines (IPCC, 1997) for medium pressure plant

Emissions of NO_x are derived for each nitric acid site using emissions data provided by the process operators directly or via the Pollution Inventory. No emissions data are available before 1994 and so a default NO_x emission factor of 3.98 tonne NO_x / kt of 100% acid produced and nitric acid production data (CIS, 1991) is used up to 1988 with emissions between 1989 and 1993 being calculated by linear interpolation.

The default emission factor is an aggregate factor based on CORINAIR (1989) emission factors for the different types of processes ranging from 3-12 t/kt of 100% acid produced. The aggregate factor is based on data on UK manufacturing plant provided by the Nitric Acid Association for the year 1985 (Munday, 1990).

Some nitric acid capacity is associated with a process that manufactures adipic acid. For the years 1990-1993, its emissions are reported combined with those from the adipic acid plant (see **Section 4.11**) but emissions from 1994 onwards are reported separately. This causes some inconsistency in between reporting categories, although total emissions are not affected.

Table 4-13 Summary of Nitric Acid Production in the UK, 1990-2011

Year	No of sites	Production (Mt 100% Nitric Acid)	Aggregate EF (kt N_2O / Mt Acid)	Aggregate EF (kt NO_X / Mt Acid)
1990	8	2.41	5.23	3.36
1994	6	2.49	3.89	1.93
1995	6	2.40	3.82	0.808
1996	6	2.44	3.83	0.743
1997	6	2.35	3.78	0.902

Year	No of sites	Production (Mt 100% Nitric Acid)	Aggregate EF (kt N_2O / Mt Acid)	Aggregate EF (kt NO_X / Mt Acid)
1998	6	2.61	3.99	0.732
1999	6	2.44	6.29	0.913
2000	6	2.03	6.94	0.992
2001	5	1.65	6.62	0.662
2002	4	1.64	4.20	0.392
2003	4	1.71	4.38	0.431
2004	4	1.71	5.00	0.438
2005	4	1.71	3.80	0.379
2006	4	1.47	3.87	0.424
2007	4	1.61	3.54	0.380
2008	4	1.29	3.65	0.234
2009	2	0.93	3.83	0.270
2010	2	1.21	3.51	0.221
2011	2	1.08	0.62	0.118

The larger of the two remaining UK plants fitted control equipment to reduce N_2O emissions in early 2011, and this will also have decreased NOx emissions from that plant as well, leading to the large decreases in the aggregate EFs for both pollutants in 2011 compared with the previous year.

4.10.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

Emissions from nitric acid production are estimated based on a combination of emission factors and reported emissions data. The methodology used to estimate N_2O for this sector does vary through the time-series depending upon the availability of data. The calculated N_2O EF for UK nitric acid production facilities varies quite significantly across the time series, and this may partially be a reflection of the lack of availability of a consistent time-series of emissions data. However, the variable N_2O EF for this sector is also a reflection of nitric acid production patterns across UK sites that utilise different process conditions with only one plant fitted with N_2O abatement. Successive closures have changed the average N_2O EF, as plants with generally above-average emission rates cease production. Abatement of N_2O at two plants has also played a part in reducing the UK emission factors over time.

For all plants in England, emissions of N_2O used in the GHG inventory are taken from emissions reported in the Pollution Inventory data from 1998 onwards. For the plant in Northern Ireland, reported emission data became available from 2001 onwards. Prior to these years in England, emissions of N_2O are estimated using either plant-specific EFs (in terms of plant capacity) based on 1998 PI data and applied to known historic plant capacity, or by applying a default emission factor of 6 kt N_2O /Mt 100% acid produced for some plant in 1990-1993. A similar approach has been used for the nitric acid plant in Northern Ireland prior to 2001, and plants operating in Scotland in the early 1990s.

The nitric acid plant emissions data are considered to be reliable since they are subject to internal QA/QC checks by the plant operators and the Environment Agency before being reported in the Pollution Inventory. More details have been obtained regarding the

abatement plant and N_2O monitoring methodologies at one UK plant with N_2O abatement fitted, and this has clarified some previous uncertainties regarding their process emissions.

4.10.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

4.10.5 Source Specific Recalculations

No recalculations have been made to this category for the 2012 submission.

4.10.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.11 SOURCE CATEGORY 2B3 – ADIPIC ACID PRODUCTION

4.11.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B3: Adipic Acid Production	CS	CS
Gases Reported	N_2O		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Adipic acid is manufactured in a multi-stage process from cyclohexane via oxidation with nitric acid. Nitrous oxide is produced as a breakdown product from the nitric acid. A single company produced adipic acid in the UK until closure of the plant in April 2009.

4.11.2 Methodological issues

There was only one company manufacturing adipic acid in the UK, but this closed in early 2009. Production data are not provided in the NIR because of commercial confidentiality concerns.

Production data and emission estimates have been estimated based on data provided by the process operator (Invista, 2010). The emission estimates are based on the use of plant-specific emission factors for unabated flue gases, which were determined through a series of

measurements on the plant, combined with plant production data and data on the proportion of flue gases that are unabated.

In 1998 an N_2O abatement system was fitted to the plant. The abatement system is a thermal oxidation unit and is reported by the operators to be 99.99% efficient at N_2O destruction. The abatement unit is not available 100% of the time, and typically achieves 90-95% availability during AA production. The abatement plant availability has a very significant impact upon the annual emissions of N_2O, and leads to somewhat variable trends in IEFs over the time-series.

A small nitric acid plant is associated with the adipic acid plant that also emits N_2O. From 1994 onwards this emission is reported as nitric acid production but prior to 1994 it is included under adipic acid production. This will cause a variation in reported effective emission factor for these years. This allocation reflects the availability of data.

4.11.3 Uncertainties and Time Series Consistency

The uncertainty analysis in Annex 7 provides estimates of uncertainty according to IPCC source category and fuel type.

Emissions of N_2O from adipic acid production are now taken from emissions reported in the Pollution Inventory, with more process-specific details also provided directly by the plant operators. In the early 1990s, emissions were received direct from the plant operators.

The level of uncertainty associated with reported emissions of N2O is not known, but the data are considered to be reliable as they are subject to QA/QC checks by the operator, by the Environment Agency (before being reported in the Pollution Inventory) and by the regulators of the UK Emission Trading Scheme (DEFRA NCCP). A higher uncertainty is assumed for 1990 than for later years. Emissions no longer occur from this source since the plant has now closed.

Fluctuations in the N_2O EF from this plant are apparent since the installation of the abatement plant. Following direct consultation with the plant operators, it has been determined that the variability of emissions is due to the varying level of availability of the abatement plant. A small change in the availability of the abatement system can have a very significant impact upon overall plant emissions and hence upon the annual IEF calculated.

4.11.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. During summer 2005, consultation between Defra, Ricardo-AEA, plant operators and the UK Meteorological Office was conducted to discuss factors affecting emissions from the adipic acid plant, including: plant design, abatement design, abatement efficiency and availability, emission measurement techniques, historic stack emission datasets and data to support periodic fluctuations in reported emissions. These discussions were intended to clarify the relationship between annual emission totals reported by the plant operators and emissions verification work conducted by the Met Office using ambient N2O concentration measurements from the Mace Head observatory in Ireland. The meeting prompted exchange of detailed plant emissions data and recalculation of back-trajectory emission models.

4.11.5 Source Specific Recalculations

No recalculations have been made to this category for the 2012 submission.

4.11.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.12 SOURCE CATEGORY 2B4 – CARBIDE PRODUCTION

This category does not occur in the UK.

4.13 SOURCE CATEGORY 2B5 – OTHER

4.13.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2B5: Sulphuric Acid Production	CS	CS, OTH
	Chemical Industry	CS	CS, OTH
	Chemical Industry (Carbon Black)	CS	CS, OTH
	Chemical Industry (Ethylene)	CS	CS, OTH
	Chemical Industry (Methanol)	CS	CS, OTH
	Chemical Industry (Nitric Acid Use)	CS	CS, OTH
	Chemical Industry (Pigment Manufacture)	CS	CS, OTH
	Chemical Industry (Reforming)	CS	CS, OTH
	Chemical Industry (Sulphuric Acid Use)	CS	CS, OTH
	Coal, tar and bitumen processes	CS	CS, OTH
	Solvent and Oil recovery	CS	CS, OTH
	Ship purging	CS	CS, OTH
Gases Reported	CO_2, CH_4, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

The UK has a large chemical manufacturing sector and emissions of methane, carbon monoxide, NO_x, SO_2, and NMVOC in the inventory are treated in some detail to reflect the many different types of process. All of these emission sources are reported under 2B5.

CO_2 emissions can occur direct from chemical processes, and estimates are made in the case of production of ammonia (see **Section 4.9**). It is possible that other chemical processes also result in direct CO_2 emissions but none have been identified. Many chemical processes report CO_2 emissions in the Environment Agency Pollution Inventory and similar data sets, but these emissions are most likely to be due to combustion processes operated as part of those chemical processes (e.g. for steam raising) and so cannot be used as evidence of process-related emissions. Chemical processes can result indirectly in emissions if wastes from the process are subsequently used as fuels and emission estimates for this type of source have been included in the inventory.

Emissions can also occur from products from the chemical industry. Sources of emissions include burning of waste products and final products (e.g. flaring and use of wastes as fuels, or burning of candles, firelighters and other products etc.) or degradation of products after disposal resulting in CO_2 emissions (including breakdown of consumer products such as detergents etc.).

After considering the magnitude of the sources in relation to the national totals, the uncertainty associated with emissions, and the likely reporting requirements in the 2006 IPCC Guidelines, emissions of carbon from the following sources were included in the 2004 GHG inventory (2006 NIR) and subsequent NIRs:

- Petroleum waxes;
- Carbon emitted during energy recovery - chemical industry;
- Carbon in products - soaps, shampoos, detergents etc; and
- Carbon in products – pesticides.

A full time series of emissions is included in the inventory, and details of the methodology for these sectors are given in Passant, Watterson & Jackson, 2007.

Chemical manufacturing processes are a significant source of NMVOC emissions. Due to the complexity of the sector and the difficulty of separating emissions from different chemical processes, almost all emissions are reported using a single, general, category.

Emissions of the remaining pollutants are less significant compared with national totals but are reported in more detail.

Methane emissions are reported separately for production of ethylene and production of methanol, these chemicals being suggested as sources by the IPCC Guidelines for National Greenhouse Gas Inventories. Ethylene was manufactured on four sites at the end of 2011 while the only methanol plant closed in 2001.

The IPCC Guidelines also suggested that methane might be emitted from manufacture of carbon black, styrene and dichloroethylene, however no evidence of any emissions of methane from these processes in the UK has been found and no estimates have been made. However, methane is emitted from other UK chemical processes and these emissions are reported as third, general, source category.

Emissions of other pollutants are reported under the following source categories:

- Chemical industry - CO, SO_2, NMVOC;
- Chemical industry (carbon black) - CO, SO_2;
- Chemical industry (nitric acid use) - NO_x;
- Chemical industry (pigment manufacture) - SO_2;
- Chemical industry (reforming) – CO;
- Chemical industry (soda ash) – CO;
- Chemical industry (sulphuric acid use) - SO_2;
- Chemical industry (titanium dioxide) – CO;
- Coal, tar and bitumen processes – NMVOC;
- Solvent and oil recovery – NMVOC;
- Ship purging – NMVOC; and
- Sulphuric acid production - SO_2.

The first source listed is the general category used where emissions occur from processes which do not fit elsewhere. The remaining categories are specific and often relate to small numbers of sites. Carbon black was being produced at two sites at the start of 2008, although one then closed at the end of that year, with the other closing in early 2009. Carbon black is manufactured by partially burning petroleum feedstocks to produce finely divided soot. The categories 'chemical industry (nitric acid use) and 'chemical industry (sulphuric acid use) refer to processes using these acids and emitting NO_X and SO_2 respectively. Manufacture of nitric acid (see **Section 4.10**) and sulphuric acid are treated separately from use. Sulphuric acid was being produced at three sites at the end of 2011. Pigment manufacture relates to a single plant where sulphur was burnt as part of the manufacturing process – this site closed in 2008. The sulphur oxides produced were largely consumed in the process, although some emissions did occur.

Reforming processes convert natural gas or other light hydrocarbons into hydrogen and carbon monoxide for use in further chemical processes, and can result in emissions of CO. Soda ash manufacture also results in some emissions of CO, which is formed during the lime manufacturing stage and then passes through the chemical processes before being emitted. These emissions are not included in the inventory category 'Lime (combustion)'. Titanium dioxide is manufactured by two routes in the UK, but one involves the use of coke as a reductant and is carried out on two sites. Carbon monoxide is emitted to atmosphere from the process. The remaining three source categories are reserved for minor sources of NMVOC. Processes involving coal-based chemicals and bitumen-based products are reported under 'coal, tar & bitumen processes', the recovery of solvents and other organic chemicals by distillation is reported under 'oil & solvent recovery', and the venting of chemical vapours from ships' tanks where cross-contamination of cargoes must be avoided, is reported under 'ship purging'.

4.13.2 Methodological Issues

The quantity of waste recovered for use as a fuel is estimated based on analysis of data reported to the Environment Agency for the years 1998-2002 and contained in the Pollution Inventory data supplied in 2005. The average mass of waste recovered for use as a fuel over these five years was 183 ktonnes. This figure was assumed applicable for all years. The wastes were characterised only as either ‘special’ or ‘non-special’ so no details were available which would allow the carbon content to be calculated. Instead the carbon content is assumed to be the same as for waste solvents used as a fuel by the cement industry.

In the case of other pollutants, emissions data for chemical processes located in England and Wales are available in the Pollution Inventory (Environment Agency, 2012). Reporting

generally started in 1994 or 1995, and few data exist for the years prior to 1994. Data for ethylene production processes in Scotland and additional data for some of the methane-emitting processes in England and Wales have been obtained from process operators and from the Scottish Pollutant Release Inventory (SEPA, 2012). The Scottish Environment Protection Agency has also, on previous occasions, supplied some data on emissions of NMVOC from individual Scottish chemical processes and additional NMVOC data for processes located in both Scotland and Northern Ireland have been obtained from process operators. Additional data on Northern Ireland's only major chemical works is provided by DoE NI (2012). The National Sulphuric Acid Association (NSAA, 2003) have provided historical emissions data for sulphuric acid production processes. Emissions from ship purging are based on a single estimate given by Rudd *et al* (1996), which is applied to all years.

All of the data available are in the form of emission estimates, usually generated by the process operators and based on measurements or calculated based on process chemistry. Emission factors and activity data are not required, although emission factors are back-calculated in the process of extrapolation of emissions back to the years prior to 1994. The extrapolation is usually linked to changes in the level of output from the chemicals manufacturing sector as measured by the 'index of output' figures published by the Office of National Statistics (2012). In a few cases, such as the figures for methane from ethylene production and SO_2 from sulphuric acid production, actual emissions data are available or can be estimated for individual plant based on actual plant capacities.

Some gaps exist in the reported data. For example, emissions from a given process will be reported for some years but not others, even though the process is known to have been operating. These gaps are presumably due to the fact that either the process operator was not required to submit emissions data or that emissions data was not or could not be supplied when requested. Most of the gaps occur in the early years of the Pollution Inventory. These gaps have been filled by copying emissions data from the nearest year for which emissions data were reported.

4.13.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

Emission estimates for 1994 onwards are mostly based on data reported by process operators and might therefore be considered accurate. However, in the absence of any detailed assessment of the methods used by individual process operators to estimate emissions, it is not possible to come to a definite conclusion. Emission estimates for NMVOC are more uncertain than the estimates for other pollutants because of the way in which these emissions were reported in the early years of the Pollution Inventory. As a result, the data have to be interpreted using expert judgement.

Emission estimates for the period prior to 1994 are also more uncertain, with the exceptions of sulphuric acid production and methane emissions. This is due to the need for extrapolation of emissions data for 1994 or some other year backwards, using general indicators of chemical industry output.

The reliability of emission estimates from 2002 onwards may deteriorate for at least some of the sources included in this sector. This is due to changes in the reporting requirements for the Pollution Inventory and other regulator's inventories, with the *de minimis* limits for

reporting of emissions of some pollutants being raised. This will lead to a slightly increased need for extrapolation of data from one year to another.

Uncertainties for the breakdown of consumer products and pesticides are high, since the assumptions are not UK specific. For the use of waste as fuel in the chemical industry, the emissions estimates are also very uncertain since the composition of the waste is not well known and the quantities burnt are estimates based on data existing for a limited number of years.

4.13.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Emissions data taken from the Pollution Inventory are subject to additional QA/QC by the Environment Agency before being used in the inventory.

4.13.5 Source Specific Recalculations

Details of and justifications for recalculations to emission factors in **Table 4-14** below, now recalculations have been made to activity data. For information on the magnitude of recalculations to Source Category 2B5, see **Section 10**.

Table 4-14 2B5 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
2B5	Chemical industry - general	CH4	Process emission	0.830	0.960	0.830	0.957	kt emissions	Correction to time series of emissions from chemical industry - other to ensure completeness

4.13.6 Source Specific Planned Improvements

Changes in the methodology are likely to be required from year to year in order to deal with changes in the data available. The intention behind these changes is to try to maintain the quality of estimates at current levels with the resources available.

4.14 SOURCE CATEGORY 2C1 – IRON AND STEEL PRODUCTION

4.14.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C1: Iron & steel flaring (BFG)	T1	CS
	Electric arc furnaces	T1	CS
	Ladle arc furnaces	T1	CS
	Following for indirect gases only:		
	Blast furnaces	CS	CS
	Basic oxygen furnaces	CS	CS
	Iron and Steel (other)	CS	CS
	Rolling Mills (Hot & Cold Rolling)	CS	CS
Gases Reported	CO_2, CH_4, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

UK iron and steel production may be divided into integrated steelworks, electric arc steelworks, downstream processes such as continuous casting and rolling of steel, and iron & steel foundries.

Integrated steelworks convert iron ores into steel using the three processes of sintering, pig iron production in blast furnaces and conversion of pig iron to steel in basic oxygen furnaces. For the purposes of the inventory, emissions from integrated steelworks are estimated for these three processes, as well as other minor processes such as slag processing.

Sintering involves the agglomeration of raw materials for the production of pig iron by mixing these materials with fine coke (coke breeze) and placing it on a travelling grate where it is ignited. The heat produced fuses the raw materials together into a porous material called sinter.

Blast furnaces are used to reduce the iron oxides in iron ore to iron. They are continuously charged with a mixture of sinter, fluxing agents such as limestone, and reducing agents such as coke. Hot air is blown into the lower part of the furnace and reacts with the coke, producing carbon monoxide, which reduces the iron ore to iron.

Gas leaving the top of the blast furnace has a high heat value because of the residual CO content, and is used as a fuel in the steelworks. Molten iron and liquid slag are withdrawn from the base of the furnace. Subsequent cooling of the slag with water can cause emissions of SO_2. The most significant greenhouse gas emissions to occur directly from the blast furnace process are the combustion gases from the 'hot stoves' used to heat the blast air.

These generally use blast furnace gas, together with coke oven gas and/or natural gas as fuels. These emissions are reported under CRF category 1A2. Gases emitted from the top of the blast furnace are collected and emissions should only occur when this gas is subsequently used as fuel. These emissions are allocated to the process using them. However, some blast furnace gas is lost and the carbon content of this gas is reported under CRF category 2C1.

Pig iron has a high carbon content derived from the coke used in the blast furnace. A substantial proportion of this must be removed to make steel and this is done in the basic oxygen furnace. Molten pig iron is charged to the furnace and oxygen is blown through the metal to oxidise carbon and other contaminants. As a result, carbon monoxide and carbon dioxide are emitted from the furnace and are collected for use as a fuel. As with blast furnace gases, some losses occur and these losses are reported with blast furnace gas losses under CRF category 2C1.

Electric arc furnaces produce steel from ferrous scrap, using electricity to provide the high temperatures necessary to melt the scrap. Emissions of carbon dioxide occur due to the breakdown of the graphite electrodes used in the furnace and NO_x is formed due to oxidation of nitrogen in air at the high temperatures within the furnace. Emissions of NMVOC and CO occur due to the presence of organic contaminants in the scrap, which are evaporated and partially oxidised. Emissions from electric arc furnaces are reported under CRF category 2C1.

The inventory contains estimates of NMVOC emissions from rolling mills. Lubricants are needed and contain organic material, some of which evaporates. These emissions are reported under 2C1. A more significant emission from rolling mills and other downstream processing of steel are those emissions from use of fuels to heat the metal. These emissions are reported under 1A2.

4.14.2 Methodological Issues

The methodology for the prediction of carbon dioxide emissions from fuel combustion, fuel transformation, and processes at integrated steelworks is based on a detailed carbon balance (this methodology is described in more detail within the section on CRF sector 1A2a). Carbon emissions from integrated steelwork are reported under 1A1c, 1B1b, 1A2a, 2A3 and 2C1, depending upon the emission source. Only carbon emissions from flared blast furnace gas and basic oxygen furnace gas are reported under 2C1.

Carbon emissions from electric arc furnaces and ladle arc furnaces are calculated using emission factors provided by Corus (2005). Energy related emissions from foundries are

included in category 1A2a but any process emissions from foundries of direct GHGs are likely to be very small and are not estimated. **Table 4-15** summarises the methods used for direct gas emissions reported under 2C1.

Table 4-15 Summary of Emission Estimation Methods for Source Categories in CRF Category 2C1

Source Category	Method	Activity Data	Emission Factors
Iron & steel - flaring	AD x EF	DECC energy statistics	Carbon: UK-specific factor from carbon balance CH_4, N_2O: EMEP/EEA
Electric arc furnaces	AD x EF	ISSB	Carbon: UK-specific factor CH_4, N_2O:EMEP/EEA
Ladle arc furnaces	AD x EF	ISSB	Carbon: UK-specific factors

Emissions of indirect gases are generally based on emissions data reported by process operators either directly to the inventory agency, or via the Environment Agency Pollution Inventory. In a few instances where emissions data are not available, literature factors are used.

4.14.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type. The sectoral Monte Carlo analysis indicates an overall uncertainty of 6% for emissions in this category.

Much of the activity data used to estimate emissions from this source category come from the Iron and Steel Statistics Bureau (ISSB) and DECC publication DUKES. Time-series consistency of these activity data are very good due to the continuity in data provided in these two publications.

4.14.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

Additional checks are undertaken for emissions from integrated steelworks with a comparison of the results of the carbon balance approach used, with emissions reported by the operator of UK integrated steelworks. This comparison is made more difficult by differences in the scope of data from different sources but the analysis still demonstrates that the carbon balance gives emission estimates that are close to those available from EU ETS sources. Incorporation of EU ETS/operator data into the inventory methodology is under review, although the differences in scope currently make it difficult to make progress in this area.

4.14.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-16** and emission factors in **Table 4-17** below. For information on the magnitude of recalculations to Source Category 2C1, see **Section 10**.

Table 4-16 2C1 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
2C1	Electric arc furnaces	Steel production (electric arc)	4.546	2.388	4.546	2.411	Megatonne	Revised steel production statistics

Table 4-17 2C1 Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
2C1	Iron and steel - flaring	Carbon	Blast furnace gas	7.932	8.583	7.932	8.192	kt / Mt	Revised energy statistics impacting on the CEFs generated from the carbon balance method.

4.14.6 Source Specific planned Improvements

Emission factors and activity data will be kept under review. Where appropriate, fuel characterisation data from verified Emission Trading Scheme datasets will be considered in future GHGI cycles.

4.15 SOURCE CATEGORY 2C2 – FERROALLOYS PRODUCTION

This category is not relevant to the UK since the early 1990s. Prior to then, some ferroalloys were produced however emissions are likely to have been very small.

4.16 SOURCE CATEGORY 2C3 – ALUMINIUM PRODUCTION

4.16.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C3: Non-Ferrous Metals (Aluminium Production)	T2, CS	CS, PS
Gases Reported	CO_2, CH_4, PFCs, CO, NO_x, SO_2, VOC		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Aluminium is produced by the electrolytic reduction of alumina at two sites in the UK at the end of 2011, although the larger of these two sites subsequently closed in early 2012. A third site closed during 2009, and a fourth process closed in mid 2000. The operational site and the recently-closed processes all use the pre-baked anode process, whereas the plant that closed in 2000 used the Soderberg Cell process. This distinction is important because of large differences in emission rates for some pollutants.

Both process types make use of carbon anodes and these anodes are consumed as the process proceeds, resulting in emissions of CO_2, CO, NMVOC and SO_2. The high temperatures necessary in the process mean that NO_x is also emitted. Finally, the PFC species tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6) are formed if the alumina content of the electrolyte falls too low. Computerised control of alumina addition to the cells is a feature of modern plant and has helped to reduce PFC emissions from aluminium production.

Emissions of methane are not estimated as there is no methodology available and emissions are considered to be negligible.

4.16.2 Methodological Issues

Emissions of carbon were estimated based on the production of aluminium for each type of process and emission factors. The carbon emission factors reflect current practice, and higher emission factors were used for earlier years, due to the production of some aluminium using the Soderberg process.

There are two aluminium smelting operators in the UK, operating at four sites. One of these sites closed in 2000, and another in 2009, leaving two sites now open, both owned by the same operator. All emissions of PFCs (CF_4 and C_2F_6) occur during the aluminium smelting process during anode effects. The estimates were based on estimates of emissions provided by the plant operators. These estimates were derived from records of the number and duration of anode effects.

Both operators use a Tier 2 methodology Smelter-specific relationship between emissions and operating parameters based on default technology-based slope and over-voltage coefficients, using the default factors for the CWPB (Centre Worked Prebaked) plant for three of the plants, and for VSS (Vertical Stud Soderberg) for the plant which closed in 2000. One of the operators used North West American Calculation assuming 3lbs PFC for every minute the cell was on anode effect, for the early part of the time series. The time series does not show any discontinuity as a result of the change in method.

Parameters for the calculation of emissions for the two operating plant in 2011 are set out below.

Table 4-18 Parameters for calculation of PFC emissions from Aluminium production in 2011

	Units	Plant 1	Plant 2
Net Hot Aluminium Produced ex Cell Rooms	mt	168,381	45,583
Anode Effects/pot day		0.45	0.03
AE Duration min/anode effect	mins	1.97	1.83
Number of cells operating	no.	325.8	79.4
CF4 Produced (IPAI)	kgs	20,822	316
C2F6 Produced (IPAI)	kgs	2,677	41

The type of smelter design has a large effect on the rate of PFC emissions. The UK industry has previously made major investment to improve their technology and all UK plants now use point feeder prebake. Large reductions in emissions of PFCs have occurred over the time series through the switch to point feeder technology. Point feeder technology is regarded as the best technology for feeding aluminium oxide into the electrolytic cells. This technology allows more regulated feeding at controlled intervals, ensuring an operating process with fewer anode effects. The move to point feeder technology not only reduces PFC emissions but improves the efficiency of the production process.

For other pollutants, some emissions data are available from the Environment Agency's Pollution Inventory for the two largest processes in England & Wales, whilst data for the

plant located in Scotland were obtained by direct contact with the plant operators, derived from emission factors calculated from the England and Wales plant emissions, or obtained from the Scottish Pollutant Release Inventory, produced by the Scottish Environment Protection Agency (SEPA).

Activity data are taken from BGS data sets for all years except 2005, 2007 and 2008 where production data available directly from the operators of each site did not agree with the BGS figure, the sum of the site-specific data being slightly higher. The BGS data was therefore replaced by the site-specific data for these years.

Methodologies used for direct gases from 2C3 are summarised in **Table 4-19**.

Table 4-19 Summary of Emission Estimation Methods for Source Categories in CRF Category 2C3

Source Category	Method	Activity Data	Emission Factors
Primary aluminium	AD x EF	BGS, operators	Carbon: UK-specific factors (defaults for Soderberg and pre-bake processes) Aluminium: Operator reported data, based on IPCC T2 method

Emissions of indirect gases are based on emissions data reported by process operators either directly to the inventory agency, or via the Environment Agency Pollution Inventory or the Scottish Pollutant Release Inventory.

The time series of emission factors and activity data used are reported in Table 4-20 below.

Table 4-20 Time series of activity data and emission factors for aluminium production

Year	Activity data	Emission factors - kt/Mt					
	Mt Al Produced	Carbon	C2F6	CF4	CO	NOx	SO2
1990	0.29	423.80	0.08	0.60	77.25	3.16	14.60
1991	0.29	423.75	0.06	0.49	77.25	3.16	14.60
1992	0.24	424.51	0.03	0.27	77.25	3.16	14.60
1993	0.24	423.35	0.02	0.21	77.25	3.16	14.60
1994	0.23	423.46	0.02	0.20	77.25	3.16	14.60
1995	0.24	423.19	0.02	0.16	77.25	3.16	14.60
1996	0.24	423.17	0.02	0.15	77.25	3.16	14.60
1997	0.25	422.91	0.01	0.12	77.25	3.16	14.60
1998	0.26	422.79	0.01	0.11	85.06	1.44	14.60
1999	0.27	422.19	0.01	0.09	80.64	1.61	15.47
2000	0.31	420.00	0.01	0.11	84.70	1.32	16.47
2001	0.34	420.00	0.01	0.08	85.89	1.31	16.24
2002	0.34	420.00	0.01	0.06	84.43	1.31	14.63
2003	0.34	420.00	0.01	0.04	83.25	1.23	14.36
2004	0.36	420.00	0.01	0.06	80.03	1.20	15.70
2005	0.37	420.00	0.00	0.04	80.12	1.18	16.80

Year	Activity data	Emission factors - kt/Mt					
	Mt Al Produced	Carbon	C2F6	CF4	CO	NOx	SO2
2006	0.36	420.00	0.01	0.05	102.00	1.15	16.10
2007	0.36	420.00	0.00	0.03	100.44	1.13	14.89
2008	0.33	420.00	0.01	0.05	99.39	1.16	15.75
2009	0.25	420.00	0.00	0.03	98.49	1.26	8.97
2010	0.19	420.00	0.01	0.08	99.09	1.27	14.25
2011	0.21	420.00	0.01	0.10	102.30	2.28	17.07

4.16.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type. The overall uncertainty for this sector is estimated at 7%.

The source of activity data is almost always from data compiled by the British Geological Survey (production of primary aluminium). This is a long running publication and the compilers of the activity data strive to use consistent methods to produce the activity data. This helps to ensure good time series consistency of the emission estimates. The alternative data used for 2005 and 2007 is only slightly higher (<0.4%) than the BGS number and supports the view that the BGS data are reliable, although the discrepancy in the 2008 data is larger (3.4%).

A large increase in emissions of PFCs between 2010 and 2011 was observed for one of the operating plants, this has been discussed with the plant operator. The increase in emissions can be explained by the pot restart programme, which is further elaborated below:

1. PFC emissions are influenced by the number of pots re-started in a given period. Stopping and starting electrolytic cells is a normal process activity, however the rate of increase in operating pots did have an effect on the emissions (62 during 2011). To restart pots requires power outages and liquid (bath and aluminium) to be transferred from 'donor' pots. The electrolysis process benefits from stability and this is impossible during a restart programme with frequent power interruptions and liquid level changes.
2. Significant effort has been put into the metal flow process from the potrooms to the casting plant to smooth out the liquid level changes and improve stability; however this has been an ongoing challenge during 2011.
3. The drive to improve energy efficiency through pot voltage reduction and increased amperage minimises the functional operating window of the pot and puts more emphasis on the definitive control of liquid levels. When increasing amperage the process becomes much more sensitive to change and the acceptable operating window much smaller. Low anode effect rates can be achieved, however much more attention to detail is required and the pot liquid levels (metal and bath) need to be well controlled. Whilst our efforts to improve energy efficiency for every tonne of aluminium produced have been successful, it has led to an increase in instability on the potlines that could be attributable to the efforts to achieve improved efficiency. A point to note is that our energy efficiency improvements have reduced carbon dioxide emissions which will offset some of the increased PFC emission.
4. Unavoidable rectiformer maintenance work throughout 2011 resulted in power interruptions contributing to the potline instability.

4.16.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Emissions data taken from the Pollution Inventory is subject to additional QA/QC from the Environment Agency.

4.16.5 Source Specific Recalculations

No recalculations have been made to this category for the 2012 submission.

4.16.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.17 SOURCE CATEGORY 2C4 – SF_6 USED IN ALUMINIUM AND MAGNESIUM FOUNDRIES

Since 2004, one of the main industry users has implemented a cover gas system using HFC 134a for some of its production capacity. Actual emissions of SF_6 for this sector are therefore reported in the CRF under 2C5 'Other metal production'. This is because the CRF Reporter does not allow reporting of HFC emissions under the 2C4 sector category. Reporting under 2C5 allows separate reporting of SF_6 and HFCs, and it was considered best to report all emissions relating to this category together.

4.18 SOURCE CATEGORY 2C5 – OTHER METAL PRODUCTION

4.18.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2C4: SF_6 Cover Gas	T2	CS, PS
	2C5: Non-Ferrous Metals (other non-ferrous metals)	T2	CS, PS
	Non-Ferrous Metals (primary lead/zinc)	T2	CS, PS
	Non-Ferrous Metals (secondary Copper)	T2	CS, PS
	Non-Ferrous Metals (secondary lead)	T2	CS, PS
Gases Reported	HFCs, SF_6, CO, SO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is		

	included in Annex 5
Major improvements since last submission	No major improvements

As described in the preceding section, (2C4 'SF_6 used in Aluminium and Magnesium Foundries') actual emissions of SF_6 and HFC134a for this sector are reported under 2C5 'Other metal production' for practical reasons, as the CRF Reporter does not allow reporting of HFC emissions under the 2C4 sector category.

SF_6 is used in the magnesium alloy and casting industry as a cover gas, to prevent molten magnesium oxidising when exposed to air. All SF_6 used in this way is released to the atmosphere unless capture/recycle technologies are employed. SF_6 is non-flammable and non-toxic, and is therefore a safe gas to use. In the UK, SF_6 has been used as an alternative cover gas to SO_2 in magnesium alloy production and sand and die-casting since the early 1990s.

In the UK, there is one large magnesium alloy producer and six smaller casting operators (three die-casting and 3 sand-casters, two of which have now closed). Alloy production involves the use of primary magnesium ingots, recycled scrap material and second-generation magnesium materials (i.e. material already made into alloys) for the production of different alloys. Both die and sand casters use these magnesium alloys to produce specific components for a wide range of industries. For the casting industry, SF_6 is used for casting specific magnesium alloys where other cover gases, such as argon, are not suitable.

UK production of many non-ferrous metals has been relatively small for many years and has declined further in recent years with the closure of the only primary lead/zinc producer in 2003 and the only secondary copper production process in 1999.

The primary lead/zinc process, the secondary copper process, and some of the secondary lead processes involve the use of coke as a reductant and emissions of CO and SO_2 from these processes are reported under 2C5. Currently, emissions of carbon from use of this coke are included with estimates for other industrial combustion (see **Section 3.2.10**), but it is recommended that this be reviewed and, if possible, emissions reported here in future. Two of the secondary lead producers also emit SO_2 from the automotive batteries that they recover lead from. Copper wire rod plants use natural gas burners to create a slightly reducing atmosphere in the melting furnace, which helps to maintain a high conductivity product. This leads to elevated emissions of CO. A few other non-ferrous metal plants have very minor emissions of CO as well.

Carbon monoxide is used as a reagent by the only UK nickel refinery and is produced by reforming of butane. Emissions from this process have been included in the NAEI estimates for chemical industry reforming processes and are reported under 2B5.

4.18.2 Methodological Issues

Magnesium alloy production
An IPCC Tier 2 methodology is used to estimate emissions.

For magnesium alloy production, SF_6 emissions from 1998 onwards were estimated based on the data reported by the company to the UK's Pollution Inventory. These data are considered accurate. Earlier emissions, before 1998, are estimated based on consultations with the manufacturers.

From 2004, one of the main industry users has implemented a cover gas system using HFC134a for some of its production capacity. There has not been a complete switch to HFC 134a, although the operator is considering this on an ongoing basis depending on suitability for the different alloys produced. In addition to having a significantly lower GWP than SF_6 (and thus reducing emissions on a CO_2 equivalent basis), use of HFC134a is further advantageous in that a significant fraction of it is destroyed by the high process temperatures thus reducing the fraction of gas emitted as a fugitive emission. The assumptions used to estimate emissions are that only 90% as much HFC134a is needed in comparison to SF_6 (consultation with industry; AEA, 2005; AEA 2008), and that 90% of the HFC cover gas used is destroyed in the production process (CSIRO 2005).

From 2008, emissions of HFCs have been reported in the Pollution Inventory, and therefore the reported data are used directly.

As part of a recent study to update the F-gas inventory, castings operators were re-contacted to provide activity data for recent years (the previous survey was conducted in 2004). Some of the operators provided new data, while for others assumed values for SF_6 use were used based on the data provided for other years.

Aluminium alloy production
No emissions of SF_6 are currently reported by any of the aluminium foundries in the Pollution Inventory. Emissions from the use of SF_6 in the UK are therefore reported as Not Occurring.

Other
Emission estimates for these processes are derived from emissions data available from the Pollution Inventory (Environment Agency, 2012). For earlier years, where no emissions data are available, emission estimates are made by extrapolation based on production of the relevant type of metal.

4.18.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

For the period 1990-1997, the estimated uncertainty in the time series data was +/- 30%. The main area of uncertainty is regarding emissions of SF_6 from casting based on discussions with the sector Trade Association. Data from the main magnesium alloy producer is also uncertain for this period.

For the period 1998-2010, the uncertainty of the time-series emissions is estimated to be significantly lower (+/- 10%). Data received from the main magnesium alloy producer are considered to be reasonably accurate.

The reported HFC emissions in 2008 to 2010 are much higher than the calculated emissions for 2004-2007. This is based on operator reported data to the regulator and is therefore considered to be accurate. A large decrease in the reported SF_6 emission has also been observed, indicating that the increased HFC emission is as a result of the continuing change over from SF_6 to HFC use. Trends in SF_6 and HFC emissions are driven by the data from the operators. Emissions of SF_6 increased from 2009 to 2010, to return to the levels seen in 2007. Emissions decreased again in 2011.

4.18.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**, and details of verification of emissions are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.18.5 Source Specific Recalculations

There have been no recalculations made to emissions from this sector.

4.18.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.19 SOURCE CATEGORY 2D1 – PULP AND PAPER & WOOD PROCESSING

4.19.1 Source Category Description

Emissions sources	2D1: Wood Products Manufacture
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

The UK paper industry is mainly confined to the production of pulp from recycled material and the production of papers using either imported virgin pulp, recycled pulp or a combination of the two. Production of virgin pulp is limited to a few processes producing mechanical or neutral sulphite semi-chemical pulp. Emissions from UK paper processes consist largely of emissions from the associated combustion processes, which supply steam and power to the papermaking processes. These emissions are reported under CRF category 1A2. Other atmospheric emissions of greenhouse gases from UK paper and pulp processes will be minor and are currently not estimated.

Emissions of NMVOC from the manufacture of chipboard, fibreboard and oriented strand board (OSB) are reported under 2D1. These products differ in the type of wood material that is made into board. Chipboard is made from assorted wood shavings, dust & chippings etc., while fibreboard is made from mechanically pulped wood fibres and OSB is made from long, thin wafers of wood with fairly uniform dimensions. All three processes involve steps for

drying of the wood particles and hot pressing of the formed board and both steps give rise to some NMVOC emissions.

4.19.2 Methodological Issues

Emissions are estimated using emission factors derived from those available in the USEPA Compilation of Air Emission Factors (USEPA, 2010). Production of the wood products is estimated from data published by the Office of National Statistics (2012). These data are given as areas or volumes of product depending upon the type of product and must be converted to a mass basis by making assumptions about the thickness and/or density of the products.

4.19.3 Uncertainties and Time Series Consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

4.19.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

4.19.5 Source Specific Recalculations

No direct greenhouse gases are reported in this section and no major methodological changes have been made this year

4.19.6 Source Specific Planned improvements

Emission factors and activity data will be kept under review.

4.20 SOURCE CATEGORY 2D2 – FOOD AND DRINK

4.20.1 Source Category Description

Emissions sources	2D2: Brewing (barley malting, fermentation, wort boiling) Bread Baking Cider Manufacture Other Food (animal feed; cakes, biscuits, cereals; coffee, malting, margarine and other solid fats; meat, fish and poultry; sugar) Spirit Manufacture (barley malting, casking distillation, fermentation, maturation, spent grain drying) Wine Manufacture
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

A number of food and drink manufacturing processes give rise to emissions of NMVOC. Most significant are emissions of ethanol from whisky maturation. Whisky is matured for a period of years in wooden barrels. This process develops the character of the whisky but an inevitable consequence is that spirit evaporates from the barrel. Other spirit manufacturing stages such as fermentation, distillation, casking (whisky only) and drying of spent grains also give rise to NMVOC emissions although these emissions are relatively small in comparison with those from maturation. Whisky manufacture is confined mainly to Scotland, which had 5 large grain distilleries and approximately 90 smaller malt distilleries at the end of 2012.. There is a single small whisky distillery in Wales and a large whiskey distillery in Northern Ireland. Scotland and England also produce other distilled spirits such as gin and vodka, with production being concentrated in Scotland.

Malt production also creates emissions of NMVOC. Malting is occasionally carried out by distilleries but most malt, both for distillers and breweries, is produced by specialist maltsters. Brewing processes such as fermentation and wort boiling and fermentation for production of cider and wine are all very minor sources of NMVOC.

Bread manufacture involves fermentation reactions and ethanol is released as a result. Most bread in the UK is made in large mechanised bakeries, of which there are about 70. The remainder is made in small –'craft bakeries'. Some other baked products include a fermentation stage and also emit ethanol. Heating of food products can cause reactions that produce organic emissions, and so processes such as drying of vegetable matter, preparation of compounded animal foods and cooking of meat and fish can cause NMVOC emissions. Finally, the processing of oils and fats is also a source of emissions, although emissions of hexane, a solvent used to extract vegetable oil from rape and other oilseeds is included in estimates of solvent use rather than as a food industry emission.

Emissions of CO_2 from this category are not estimated since no appropriate data are available.

4.20.2 Methodological Issues

Emissions of NMVOC from food and drink manufacture are all calculated using emission factors and activity data obtained from either industry or Government sources. In the case of whisky maturation, data are available for volumes of whisky in storage at the end of each year from the Scotch Whisky Association (2011), and so emissions can be calculated by applying an annual emission rate factor with the average volume of whisky in storage for each year. This is more accurate than using an overall emission factor applied to whisky production since whiskies are stored for varying lengths of time and stock levels will rise or fall depending upon production, demand and changes in the length of maturation required.

NMVOC emission factors for food and drink, are shown below.

Table 4-21 NMVOC Emission Factors for Food and Drink Processing, 2011

Food/Drink	Process	Emission Factor	Units
Beer	Barley Malting Wort Boiling Fermentation	0.6[c] 0.0048[c] 0.02[c]	g/L beer
Cider	Fermentation	0.02[c]	g/L cider
Wine	Fermentation	0.2[c]	kg/m^3

Food/Drink	Process	Emission Factor	Units
Spirits	Fermentation	1.58[d]	g/ L alcohol
	Distillation	0.79[g]	g/ L alcohol
	Casking	0.40[h]	g/ L whiskey
	Spent grain drying	1.31[i]	kg/ t grain
	Barley Malting	4.8[c]	kg/ t grain
	Maturation	15.78[d]	g/ L alcohol
Bread Baking		1[a]	kg/tonne
Meat, Fish & Poultry		0.3[f]	kg/tonne
Sugar		0.020[b]	kg/tonne
Margarine and solid cooking fat		10[f]	kg/tonne
Cakes, biscuits, breakfast cereal, animal feed		1[f]	kg/tonne
Malt production (exports)		4.8[c]	kg/ t grain
Coffee Roasting		0.55[f]	kg/tonne

a Federation of Bakers (2000)
b Environment Agency (2007)
c Gibson *et al* (1995)
d Passant *et al* (1993)
e Assumes 0.1% loss of alcohol based on advice from distiller
f EMEP/CORINAIR, 2006
g Unpublished figure provided by industry
h Based on loss rate allowed by HMCE during casking operations
i US EPA, 2007

4.20.3 Uncertainties and Time Series Consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

Emissions of direct greenhouse gases from this source category will be minor and are currently not estimated.

4.20.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

4.20.5 Source Specific Recalculations

No direct greenhouse gases are reported in this section and no major methodological changes have been made this year

4.20.6 Source Specific Planned improvements

Emission factors and activity data will be kept under review.

4.21 SOURCE CATEGORY 2E – PRODUCTION OF HALOCARBONS AND SF_6

4.21.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2E1 and 2E2: Halocarbons Production (By-Product and Fugitive)	T2	PS
Gases Reported	HFCs, PFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Emissions arise from the UK manufacture of HFCs, PFCs and HCFC 22. HFC 23 is a by-product of HCFC 22 manufacture. There are two single manufacturers of HFCs and PFCs respectively in the UK, and two companies were operating HCFC 22 plants, one of which closed in 2008, and the second closed at the end of 2009. Data from these sectors have been aggregated to protect commercial confidentiality.

There is no UK production of SF_6.

4.21.2 Methodological Issues

A full description of the emission model and associated methodology used for this sector is contained in AEA (2008). Within the model, manufacturing emissions from UK production of HFCs, PFCs and HFC 23 (by-product of HCFC 22 manufacture) are estimated from reported data from the respective manufacturers. Manufacturers have reported both production and emissions data, but only for certain years, and for a different range of years for different manufacturers. Therefore the emissions model is based on implied emission factors, and production estimates are used to calculate emissions in those years for which reported data was not available. Two of the three manufacturers were members of the UK greenhouse gas Emissions Trading Systems. As a requirement of participation in the scheme, their reported emissions are verified annually via external and independent auditors. For PFC production, emissions are now reported to the Environment Agency's Pollution Inventory, and these emissions are directly used within the GHG inventory. The operator of the HFC and (now closed) HFC 22 plant provides speciated emissions data directly to the inventory agency, based on vent analysis and flowmeter readings, or on weighbridge differences. The other HCFC 22 plant, which closed in 2008, also reported to the PI and these emissions were used within the GHG inventory.

All emissions from the production of HFCs, PFCs and HCFC-22 are reported in CRF category 2.E.2. The categories are aggregated at the request of the operators, to protect commercially confidential information. Activity data are not reported, for the same reason.

4.21.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 7**, shown in **Section A7.6**, provides estimates of uncertainty according to IPCC source category and fuel type. The uncertainty estimate for emissions from HFC manufacture has been revised for this submission, based on information from the plant operator. The uncertainty is now estimated at 10%.

There is a significant decrease in HFC emissions in 1998/1999. This step-change in emissions is due to the installation of thermal oxidiser pollution abatement equipment at one of the UK manufacturing sites. Fugitive HFC emissions from both an HCFC22 plant and HFC manufacturing plant (run by the same operator) are treated using the same thermal oxidiser unit. Emissions also decrease in 2004, reflecting the installation of a thermal oxidiser at the second of the UK's HCFC22 manufacturing sites. This was installed in late 2003, and became fully operational in 2004. HFC 23 emissions decreased in 2009 and 2010 following the closure of both HCFC 22 manufacturing sites. A small emission of HFC 22 remains, which arises from the production of HFC 125, most likely due to impurities in the feedstock.

A significant increase in PFC emissions from the production of halocarbons is observed from 1992 to 1996 (with the trend changing after 1996). The increase in emissions was due to increasing production levels at the single UK manufacturing plant during this period. Since 1996, the level of emissions have changed each year which broadly reflects the demand (and hence production levels) for PFCs. In 2004 and 2005, emissions reported by the company increased compared with the preceding 3 years of fairly stable emission levels 2001-2003. Emissions declined sharply in 2007-2009, before increasing again in 2010 and 2011.

4.21.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**, and details of verification of emissions are given in **Annex 10**. Additionally, as described above in **Section 4.21.2**, two of the UK manufacturing plants also had their emissions externally validated as part of the requirements of the UK Emissions Trading System. Data reported via the Pollution Inventory are also further checked by the Environment Agency.

Trilateral F-gas Peer Review

A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.21.5 Source Specific Recalculations

No recalculations have been made to emissions from this sector.

4.21.6 Source Specific Planned Improvements

There are currently no planned improvements for this sector, however data sources will be kept under review.

4.22 SOURCE CATEGORY 2F1 – REFRIGERATION AND AIR CONDITIONING EQUIPMENT

4.22.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F1: Commercial Refrigeration	T3	CS
	Domestic Refrigeration	T3	CS
	Industrial Refrigeration	T3	CS
	Mobile Air Conditioning	T3	CS
	Refrigerated Transport	T3	CS
	Stationary Air Conditioning	T3	CS
Gases Reported	HFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using a suitable scaling factor (population, GDP etc).		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.		

HFCs and HFC blends have been widely used as replacement refrigerants for ozone depleting substances across virtually all refrigeration end-uses. They generally share many of the properties of CFC and HCFC refrigerants, namely low toxicity, zero and/or varying degrees of flammability and acceptable materials compatibility. Emissions of HFCs can occur at various stages of the refrigeration/air-conditioning product life-cycle:

- During the refrigeration equipment manufacturing process;
- Over the operational lifetime of the refrigeration or air-conditioning unit; and
- At disposal of the refrigeration or air-conditioning unit.

This emission category contains aggregated emission estimates from the end-uses summarized in the table below. As shown, the UK inventory uses a code (RAC-1 to RAC-13) to refer to these sector sub-divisions.

Table 4-22. Model End-Uses and Definitions

Revised Model End-Use		Description
RAC-1	Domestic Refrigeration	Refrigerated appliances including refrigerators, chest freezers, upright freezers, and fridge freezers.
RAC-2	Small Commercial Stand-Alone Refrigeration Units	Small, hermetic, stand-alone refrigeration units including ice cream cabinets and drinking water coolers. These systems are commonly used in retail food stores but are also found in pubs, restaurants, and other hospitality and catering outlets such as hotels, hospitals, and schools.
RAC-3	Condensing Units	Refrigeration systems composed of one (or two) compressor(s), one condenser, and one receiver assembled into a unit, which is located external to the sales area. These units are typically installed in small shops and have refrigeration capacities ranging from 1 kW to 20 kW.
RAC-4	Centralised Refrigeration Systems	Refrigeration systems that are comprised of racks of compressors installed in a machinery room. These systems are commonly used in supermarket applications.
RAC-5	Industrial Systems	Refrigeration systems including industrial process refrigeration and cold storage.
RAC-6	Small Stationary Air Conditioning	Includes small self-contained ACs (including window units) and non-ducted split ACs. Units are used primarily in commercial applications, but there is some use in the residential sector. System cooling capacities typically range from 3 to 12 kW.
RAC-7	Medium Stationary Air Conditioning	Includes ducted split, variable refrigerant flow (VRF) non-ducted split, ducted split, and packaged AC. Units are used in the commercial UK sector. System cooling capacities typically range from 12 to 30 kW.
RAC-8	Large Stationary Air Conditioning (Chillers)	Large, indirect chillers used for commercial comfort air conditioning.
RAC-9	Heat Pumps	Residential and small commercial heat pumps, including air-source heat pumps (ASHP) (air-to-air and air-to-water systems) and ground-source heat pumps (GSHP).
RAC-10	Land Transport Refrigeration	Refrigerated road vehicles (i.e., light commercial vehicles, trucks, trailers) and intermodal containers.
RAC-11	Marine Transport Refrigeration	Refrigerated general cargo ships, container ships and fishing vessels (1,000 GT and above).
RAC-12	Light Duty Mobile Air Conditioning	AC systems for passenger cars and light commercial vehicles (up to 3.5 tonnes). Both of these vehicle types are covered under Directive 2006/40/EC (the MAC Directive).
RAC-13	Other Mobile Air Conditioning	AC systems for trucks (over 3.5 tonnes), buses/coaches, semi-trailers, trailers, and railcars.

4.22.2 Methodological Issues

The previous version of the refrigeration/air conditioning inventory model developed by AEA (2010) was updated by ICF International in the summer/autumn of 2011 based on revised industry input and a more transparent, robust Tier 2 modelling approach. Specifically, the model was reorganized from nine to 13 end-uses, for which detailed assumptions were developed to utilise a fully bottom-up approach. Since most end-uses defined by the previous version of the model were modelled using a top-down approach, many input assumptions were developed for the first time. This transition from a largely top-down approach (based on total refrigerant sales data) for estimating the UK's refrigeration and air

conditioning emissions to a fully bottom-up approach (based on equipment stocks and average charge size from available market data) was performed in order to improve the accuracy of emissions allocated to end-uses and improve the understanding of the end-uses to better inform policy.

For all end-uses, market data and other country-specific information were considered in the development of assumptions on equipment stocks, market growth, equipment lifetimes, refrigerant market penetrations, charge sizes, manufacturing loss rates, operational loss rates, and disposal loss rates for each end-use across the 1990-2050 time series. To revise and develop new input assumptions, an extensive literature review was conducted and key industry stakeholders were contacted. Priority industry stakeholders were selected across all end-uses and initially contacted to fill data gaps and corroborate information found in the literature. Following the development of preliminary assumptions for all end-uses, draft assumptions were then shared with a broader range of stakeholders to solicit additional industry input and vet assumptions.

In developing modelling input assumptions by end-use, expert judgment was applied to select appropriate values when more than one estimate was provided by literature and/or stakeholders. In general, more weight was given to estimates that are UK- or regional specific and/or more recent. In cases of equal data quality where numerous data points were available, values were selected based on the mid-point of the data range. Where no UK- or EU-specific information was available, the 2000 Intergovernmental Panel on Climate Change (IPCC) Good Practice Guidance default assumptions were relied on to estimate emissions. The 1996 and 2006 IPCC reports were also reviewed and considered, but the latter (most recent) assumptions could not be adopted at this time without additional supporting information, per IPCC guidance.

In the process of finalising the input assumptions, an analysis was conducted to compare estimated refrigerant consumption (calculated as the amount of refrigerant used to manufacture new equipment produced in the UK plus the amount used to service leaking equipment) with annual refrigerant sales data from the British Refrigeration Association (BRA). Following the comparison, assumptions were adjusted as deemed appropriate to further align the model output with the BRA data. A summary table of the 2010 input assumptions is provided below. A full description of the methodology, sources, and input assumptions used to update emission estimates by end-use is contained in ICF (2011).

Table 4-23 Summary of 2011 Input Assumptions by End-Use

Application		2011 Parameters							
CRF Sector	UK Category	Total Stock (units)[a]	Total Sales (units)[a]	Lifetime (years)	Charge (kg)[a]	Refrigerants in New Equipment	Manufacturing Loss Rate	Operational Loss Rate	Disposal Loss Rate
Domestic Refrigeration	Domestic Refrigeration	40,793,870	2,895,318	15	0.10	HFC-134a, HCs	0.6%	0.3%	35%*
Commercial Refrigeration	Small Hermetic Stand-Alone Refrigeration Units	2,472,000	298,487	10	0.5	HFC-134a, R-404A, R-407C, HCs	1%	1.5%	40%*
	Condensing Units	609,000	48,293	14*	5*	HFC-134a, R-404A, R-407A, R-407F,R-410A, R-507, HCs	2%	10%	15%
	Centralised Supermarket Refrigeration Systems	112,373,000 (m^2)	10,439,793 (m^2)	18*	0.26 (kg/m^2)	HFC-134a, R-404A, R-407A, HCs, R-717, R-744	2%	17%	8%
Transport Refrigeration	Land Transport Refrigeration	88,954	13,497	7	3.9	HFC-134a, R-404A	0.2%	14.8%	20%
	Marine Transport Refrigeration	527	32	25*	1,500*	R-404A, R-407C, R-717	1%	39%	29%
Industrial Refrigeration	Industrial Systems	20,400	907	25*	65	HFC-134a, R-404A, R-407C, R-410A, R-507, HCs, R-717, R-744	1%	8%	15%
Stationary Air-Conditioning	Small Stationary Air Conditioning	4,865,614	431,111	13	1.5	R-407C, R-410A	0.5%	3%	30%
	Medium Stationary Air Conditioning	645,750	55,576	15	15	R-407C, R-410A	1%	6%*	30%
	Large Stationary Air Conditioning (Chillers)	41,616	2,169	18	180	HFC-134a, R-407C, R-410A, R-717	0.5%	3%	20%
	Heat Pumps	25,338	5,118	15	3	HFC-134a, R-404A, R-407C, R-410A	1%	6%*	34%*
Mobile Air-Conditioning	Light Duty Mobile Air Conditioning	28,221,902	1,632,936	15	0.724	HFC-134a	0.5%	10%	30%
	Other Mobile Air Conditioning	505,657	66,381	10	4*	HFC-134a, R-407C	0.5%	10%	30%

[a] Except where otherwise noted.

* Estimates fall outside of the IPCC (2000) range but are in line with UK- and/or EU-specific estimates provided by industry or in the published literature.

Speciated emissions are now reported for the OTs and CDs under 2F1. Emission estimates from the UK GHGI were scaled by a territory-specific indicator. Relevant indicators include territory population, GDP and number of cars. The indicators for each activity were chosen based on expert judgement and were dependent on the information available for each territory. This is the first submission in which speciated f-gas emissions have been reported for the overseas territories and crown dependencies.

4.22.3 Uncertainties and Time-Series Consistency

Tier 2 quantitative uncertainty analyses for 1995 (base year) and 2010 were conducted to identify the uncertainty associated with the model output. To calculate uncertainty, functional forms were developed to simplify some of the complex aspects of the refrigeration and air-conditioning sector. In particular, because emissions are calculated based on the entire lifetime of equipment, not just equipment put into commission in the current year, simplifying equations were used. The functional forms used variables that included growth rates, lifetimes, emission factors (manufacturing, operational, and disposal emission rates), refrigerant transitions, charge size, disposal quantities, and new and existing stock. Uncertainty was estimated around each variable within the functional forms based on ICF's expert judgment, taking into account the range of estimates provided in the literature and by industry stakeholders. A Monte Carlo simulation analysis was performed and uncertainty bounds were generated using 10,000 simulations.

The results of the analysis indicate a range of approximately 5% below and 6% above the 1995 emission estimate, and approximately +/-5% around the 2010 emission estimate. The most significant sources of uncertainty include the emission factors for centralised supermarket refrigeration systems and marine transport refrigeration—two end-uses with a significant installed base of refrigerant (due to large stock and/or charge size). The 2010 uncertainty estimates have been applied to 2011 in the Monte Carlo analysis for the GHG inventory.

4.22.4 Source Specific QA/QC and Verification

End-use input assumptions used to generate the refrigeration and air conditioning emissions were developed based on industry consultation and were peer-reviewed. Further, to verify the emissions estimates generated by the revised model, the results were compared with the sales data provided by BRA. The results of the comparison reveal that the data sets align closely, with the revised model output showing the same trends and totalling only about 5% above the collective annual BRA data for HFCs from 2006-2010.

Historic emissions estimates generated by the revised model were also compared with concentration observations captured by the dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment) for the years 1995 through to 2008. Results of this comparison show that the revised model output aligns significantly more closely to the NAME observations than historic inventory estimates. More information relating to atmospheric measurements and verification of UK emissions estimates is provided in **Annex 10**.

A list of industry stakeholders consulted on the input assumptions, as well as detailed results from the BRA and emission observation comparisons are discussed in more detail in ICF (2011).

4.22.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-24** below. For information on the magnitude of recalculations to Source Category 2E, see **Section 10**.

Table 4-24 2F1 Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
2F1	Commercial Refrigeration	HFCs	0.000	3.094	0.000	3.144	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.
2F1	Domestic Refrigeration	HFCs	0.000	0.223	0.000	0.224	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.
2F1	Industrial Refrigeration	HFCs	0.000	0.230	0.000	0.234	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.
2F1	Mobile Air Conditioning	HFCs	0.000	4.649	0.000	4.694	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.
2F1	Refrigerated Transport	HFCs	0.000	0.854	0.000	0.868	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.
2F1	Stationary Air Conditioning	HFCs	0.000	1.783	0.000	1.807	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.

4.22.6 Source Specific Planned Improvements

Emission factors, model parameters, and activity data will be kept under review. A number of potential updates have been identified to further improve upon the emission estimates from this source, including additional stakeholder consultation in the (non-food) industrial refrigeration and marine transport refrigeration sectors. These tasks will be added to the improvement programme; although they are currently not considered a high priority, they should be considered if resources are available.

4.23 SOURCE CATEGORY 2F2 – FOAM BLOWING

4.23.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F2: Foams	T3	CS
Gases Reported	HFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All relevant emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using GDP.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Emissions of HFCs from foams can occur as follows:

- During the manufacturing process;
- Over the lifetime of the foam; rigid foams are closed cell foams and the blowing agent is designed to remain in the foam and contributes to its performance. Loss of HFCs is undesirable as it may affect the performance of the foam but is estimated to occur, albeit at a low rate; and
- At disposal of the foam.

Emissions at each point vary according to the type of foam. Typically, of the HFC used in the production process, less than 10% is emitted during manufacture (although emissions may be as high as 40 to 45 % for some types of foam), less than 1% per year over the useful lifetime of the product and the remainder on disposal.

4.23.2 Methodological Issues

The methodology used to estimates emissions corresponds to the IPCC Tier 2 'bottom-up' approach. The emission factors from the sector have been summarised in **Annex 3 Section A3.4.5.3**.

Emissions are considered separately from the following categories of foams:

PU Appliances (F1); PU Flexibly faced laminate (F2); PU Discontinuous Panel (F3); PU Continuous Panel (F4); PU, PIR, Phenolic block (F5); PIR, Phenolic flexibly faced laminate (F6); PU Spray/injected/pipe-in-pipe (F7); Extruded polystyrene (XPS) (F8); Polyethylene Foam (F9); Integral Skin Foam (F10)

A full description of the emissions and associated methodology used for this sector is contained in AEA (2010). The emissions for the years 1990 to 2002 are based on data from March (1999). Emissions data for recent years (2003 onward) were obtained from UK industry experts. The methodology used estimates the bank of fluid used by considering the consumption of fluid in each foam sub-sector, together with corrections for imports, exports, disposal and emissions. Once the size of the bank in a given year is known, the emission can be estimated by application of a suitable emission factor. Emissions are also estimated from the production stage of the equipment and during disposal.

The species used for foam blowing are given below.

Table 4-25 Species according to application for foam blowing

Application	HFC-245fa	HFC-365mfc	HFC-227ea	HFC-134a	HFC-152a
PU Boardstock	25%	67.5%	7.5%		
PU Cont. Panel		90%	10%		
PU Disc. Panel		90%	10%		
PU Spray	100%				
PU P-i-P		90%	10%		
PU Block - Slab		90%	10%		
PU Block - Pipe		90%	10%		
XPS				65%	35%
PF Boardstock		90%	10%		
PF Disc. Panel		90%	10%		
PF Block - Slab		90%	10%		
PF Block - Pipe		90%	10%		
PU - Appliance	50%	45%	5%		
PU - Reefer	50%	45%	5%		

Table 4-26 sets out the bank size and emissions of HFCs by species and by foam type for 2011. No emissions are occurring for this source in 1990 or in 1995. The bank also includes HFC species not currently reported in the UK GHG inventory, since no GWP was available in the SAR (HFC-365mfc, HFC-245fa).

Table 4-26 Bank size and emissions for foams

Foam type		PU Boardstock	PU Cont. Panel	PU Disc. Panel	PU Spray	Other PU	XPS Board	Phenolic Foam
Size of Bank (tonnes HFC)		2962.5	3487.8	451.0	215.9	236.9	6104.6	1537.6
Emissions (tonnes)	HFC-134a	0.00	0.00	0.00	0.00	0.00	191.73	0.00
	HFC-152a	0.00	0.00	0.00	0.00	0.00	103.24	0.00
	HFC-227ea	6.77	2.57	0.87	0.00	1.46	0.00	4.08

Speciated emissions for the OTs and CDs are now reported under 2F2. Emission estimates from the UK GHGI were scaled using the GDP of each territory. This is the first submission in which speciated f-gas emissions have been reported for the overseas territories and crown dependencies.

4.23.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry. Time-series data was estimated to have an uncertainty range of +/-30% for this sector. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

4.23.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions are given in **Annex 10**.

Trilateral F-gas Peer Review

A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.23.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-27** below. For information on the magnitude of recalculations to Source Category 2F2, see **Section 10**.

Table 4-27 2F2 Source specific recalculations since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
2F2	Foams	HFCs	0.000	0.299	0.000	0.302	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.

4.23.6 Source Specific Planned improvements

Emission factors and activity data will be kept under review.

4.24 SOURCE CATEGORY 2F3 – FIRE EXTINGUISHERS

4.24.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F3: Fire Fighting	T3	CS
Gases Reported	HFCs, PFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All relevant emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using GDP.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

In the UK, manufacturers of fixed suppression systems for fire fighting have been using HFCs as an alternative to Halons for the past 12-13 years. HFC-based systems are used for the protection of electronic and telecommunications equipment, and in military applications, records offices, bank vaults and oil production facilities.

The main HFC used in UK fixed systems is HFC 227, with some use of HFC 23 and HFC 125. The majority of emissions of HFCs will occur when the system is discharged, either when triggered accidentally or during a fire. Minimal emissions may also occur during filling or maintenance of the systems.

As well as HFCs being used to replace Halon-based systems in the mid-1990s, a small quantity of PFC (mainly C4F10) was imported by a US company into the EU to be used as an alternative fluid in fire fighting fixed systems. The main application of these PFC-based fixed systems is for fire protection of flooding closed rooms (e.g. control rooms). Imports for new systems stopped in 1999, as this application of PFCs was not regarded as an essential use. The F gas Regulation banned the sale of new PFC-based systems in 2007. For purposes of recharge, PFCs are still supplied. By 2010 it is assumed there are no fixed systems using PFCs in the EU.

4.24.2 Methodological Issues

The methodology used to estimates emissions corresponds to an IPCC Tier 2 method. The emission factors for HFC use in the sector have been summarised in **Table 4-28** below.

Emissions for this sector were calculated using the same emission model as used for the UK's previous submission, updated based on the findings of a recent study (AEA, 2008). Emissions estimates were obtained from March (1999) for years 1990-1996 and for subsequent years from the representative UK trade organisation, the Fire Industry Council (FIC) and from ASSURE. The emissions data are based on estimates of installed capacity and an annual emission rate of approximately 5% per annum until 2000 and decreasing to 2.6% by 2005 (an assumption based discussion with industry representatives). There are no emissions from HFC prior to 1995. A full description of the associated methodology used is contained in AEA (2008). The sector was reviewed in 2010 (AEA, 2010) and no updates were introduced.

Emissions of PFCs were < 1kt on a GWP basis in 2009, no emissions occur from 2010 onwards.

Table 4-28 Key assumptions used to estimate HFC emissions from fire extinguishers

	Parameter	1990	1995	2011
Activity data	HFC species and ratio HFC 227ea : HFC 23	97.5 : 2.5	97.5 : 2.5	97.5 : 2.5
	Size of bank (t)			2534
	Used for manufacture	0	20	90
	Equipment lifetime (yrs)	0	20	n/a
Emission factors	% released through fire	n/a	n/a	1.5
	% released through servicing	1.5	1.5	1.0
	% released during recovery	3.4	3.4	0.1
		0.1	0.1	
	PM %			0
	PL %	0	0	2.5
	D %	4.9	4.9	0.1

Speciated emissions for the OTs and CDs are now reported under 2F3. Emission estimates from the UK GHGI were scaled by the GDP of each territory. This is the first submission in which speciated f-gas emissions have been reported for the overseas territories and crown dependencies.

4.24.3 Uncertainties and Time Series Consistency

Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry. Uncertainties in emissions over the 1990-2005 period were estimated to be +/- 10%, and estimates from 2005 onwards are thought to be more uncertain (around 20%) since these are based on projections and anecdotal evidence. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

4.24.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.24.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-29** below. For information on the magnitude of recalculations to Source Category 2F3, see **Section 10**.

Table 4-29 2F3 Source specific recalculations since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
2F3	Firefighting	HFCs	0.000	0.204	0.000	0.205	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.

4.24.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

4.25 SOURCE CATEGORY 2F4 – AEROSOLS/ METERED DOSE INHALERS

4.25.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F4: Metered Dose Inhalers Aerosols (Halocarbons)	T3	CS
Gases Reported	HFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All relevant emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using population data.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

Most aerosols use hydrocarbon propellants, with a relatively small proportion of the market favouring DME. Compressed gases are used in very few aerosols since they suffer from a number of disadvantages compared with liquefied gas propellants such as DME and hydrocarbons. HFCs are used only in a few applications. The most important industrial applications in volume terms are air dusters and pipe freezing products; other applications include specialised lubricants and surface treatments, and specialised insecticides. The use of HFCs for novelty applications, such as 'silly string' is now banned, from July 2009, under the EC Regulation on fluorinated greenhouse gases (EC 842/2006).

Metered dose inhalers (MDIs) are used to deliver certain pharmaceutical products as an aerosol. For patients with respiratory illnesses, such as asthma and chronic obstructive pulmonary disease (COPD), medication needs to be delivered directly to the lungs. MDIs are one of the preferred means of delivering inhaled medication to patients with these illnesses. MDIs originally used CFC propellants but, as with industrial aerosols, concern over ozone destruction led to attempts to replace CFCs with HFCs.

4.25.2 Methodological Issues

Aerosols

The methodology used to estimates emissions corresponds to an IPCC Tier 2 method.

Aerosol HFC emission estimates have been derived on the basis of fluid consumption data provided by BAMA. An average product lifetime of one year for all aerosols containing HFC

has been assumed, based on discussions with BAMA, although this may be shorter or longer depending on the specific aerosol application. It is estimated that 1% of HFC emissions from aerosols occur during manufacture. The majority is released during the product lifetime (97%), with end of life emissions accounting for the other 2%. These emission factors are the same as those estimated in previous work by March (1999). The lifetime and end of life emissions are calculated after import and exports have been taken into account.

Metered Dose Inhalers (MDIs)
The methodology used to estimates emissions corresponds to an IPCC Tier 2 method. The MDI methodology is follows an IPCC Tier 2 bottom-up analysis, based on estimates of the number of units (inhalers) used annually and estimates of the amount of HFC in each inhaler. Data on MDI use in 2001 was provided by the major UK manufacturers of MDIs; the trend from 2001 to 2010 is based on estimate of UK share of estimated EU emissions in 2010 (ECCP, 2001).

Although the amount of HFC in each inhaler differs between manufacturers, an average amount was calculated of 17 g/MDI. MDIs were assumed to emit 96% of total HFC contained during the lifetime usage: 2% of emissions occur during manufacture and 2% at end-of-life. Import and export levels have been based on data provided by manufacturers, and estimates of the UK market for MDI usage.

The date the estimates from this sector were last updated is 2005. Emissions from the sector were reviewed in 2010 (AEA, 2010), but left unchanged.

Aerosols

Table 4-30 Key assumptions used to estimate HFC134a emissions from aerosols

	Parameter	1990	1995	2011
Activity data	Used for UK manufacture (tonnes)	8.7	339.6	582.1
	Exported (tonnes)	0.87	33.96	36.6
	Imported (tonnes)	0	0	303.0
	Product lifetime (yrs)	1	1	1
Emission factors	PM %	1	1	1
	PL %	97	97	97
	D%	2	2	2

Table 4-31 Key assumptions used to estimate HFC152a emissions from aerosols

	Parameter	1990	1995	2011
Activity data	Used for UK Manufacture (tonnes)	0.267	10.39	46.6
	Exported (tonnes)	0.0267	1.039	25.0
	Imported (tonnes)	0	0	0.0
	Product lifetime (yrs)	1	1	1
Emission factors	PM %	1	1	1
	PL %	97	97	97
	D %	2	2	2

Metered Dose Inhalers (MDIs)

Table 4-32 Key assumptions used to estimate HFC134a emissions MDIs

	Parameter	1990	1995	2011
Activity data	HFC species and ratio HFC 134a : HFC 227ea	80:20	80:20	80 : 20
	% exported			86
	Total HFC used for manufacture (tonnes)	0	0	2,505
	Size of bank (t)	0.8	0.8	769.6
	Product lifetime (yrs)	0.784	0.817	1
Emission factors	PM %	1	1	2
	PL %	2	2	96
	D %	96	96	2

Table 4-33 Key assumptions used to estimate HFC227ea emissions MDIs

	Parameter	1990	1995	2011
Activity data	HFC species and ratio HFC 134a : HFC 227ea	80:20	80:20	80 : 20
	% exported			86
	Total HFC used for manufacture (tonnes)	0	0	626.4
	Size of bank (t)	0.2	0.2	192.4
	Product lifetime (yrs)	0.196	0.204	1
Emission factors	PM %	1	1	2
	PL %	2	2	96
	D %	96	96	2

Speciated emissions for the OTs and CDs are now reported under 2F4. Emission estimates from the UK GHGI were scaled by the population of each territory. This is the first submission in which speciated f-gas emissions have been reported for the overseas territories and crown dependencies.

4.25.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry. The uncertainty for aerosol emissions was estimated to be +/- 15-20%, based on uncertainties surrounding the estimation of import and export markets, and reliance on estimates from previous work (March 1999).

For MDIs, the uncertainty was estimated to be +/- 30-40%, a relatively high uncertainty due to the use of approximations of the use of HFCs in MDIs for research work, and assumptions that had to be made concerning the import / export market, domestic market and number of doses used in the UK annually. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

4.25.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions are given in **Annex 10**.

Trilateral F-gas Peer Review

A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.25.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-34** below. For information on the magnitude of recalculations to Source Category 2F4, see **Section 10**.

Table 4-34 2F4 Source specific recalculations since previous submission

IPCC Category	Source Name	Activity Name	2011 submission		2012 submission		Units	Comment/Justification
			1990	2009	1990	2009		
2F4	Aerosols - halocarbons	HFCs	0.010	1.107	0.010	1.114	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.
2F4	Metered dose inhalers	HFCs	0.002	1.583	0.002	1.593	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.

4.25.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.26 SOURCE CATEGORY 2F5 – SOLVENTS

4.26.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F5: Precision Cleaning	T3	CS
Gases Reported	HFCs		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Not occurring		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

HFCs can be used as solvents in a range of applications such as precision cleaning to replace CFCs, HCFCs or 1,1,1-trichloroethane. HFCs have been developed that are used for precision cleaning in sectors such as aerospace and electronics.

4.26.2 Methodological Issues

The methodology used to estimates emissions corresponds to an IPCC Tier 2 method. Emission factors are not quoted for this sector, as the data available only allows estimates of "lifetime" emissions to be calculated.

UK estimates of emissions from this source are based on a European evaluation of emissions from this sector (Harnisch and Schwarz, 2003), subsequently disaggregated to provide a top-down UK estimate. This data source is becoming dated, and some of the assumptions in it are likely to have been superceded. As such, a review of available data for this source will be added to the improvement programme.

Table 4-35 Key assumptions used to estimate emissions from the use of solvents

	Parameter	1990	2005	2011
Activity data	EU Estimate (tonnes of HFC released)	0	0	600
	UK Estimate (tonnes of HFC released)	0	0	82.5
	Product lifetime (yrs)	n/a	n/a	n/a
Emission factors	PM %	n/a	n/a	n/a
	PL %	n/a	n/a	n/a
	D %	n/a	n/a	n/a

4.26.3 Uncertainties and Time Series Consistency

The uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and fuel type.

Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2004), based on an understanding of the uncertainties within the sector and from discussion with industry.

There is a relatively high uncertainty estimated for emissions from this sector (+/- 25%). Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

4.26.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.26.5 Source Specific Recalculations

There have been no recalculations to emissions from this sector..

4.26.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

4.27 SOURCE CATEGORY 2F7 – SEMICONDUCTOR MANUFACTURE

Emissions of SF_6 from semiconductor manufacturing are combined with emissions from training shoes and electrical insulation in source category 2F9 for reasons of commercial confidentiality. This source category is described in **Section 4.29**.

4.28 SOURCE CATEGORY 2F8 – ELECTRICAL EQUIPMENT

Emissions of SF_6 from electrical equipment (insulation in electrical transmission and distribution – e.g. switchgear) are combined with emissions from training shoes and semiconductor manufacture in source category 2F9 for reasons of commercial confidentiality. This source category is described in **Section 4.29**.

4.29 SOURCE CATEGORY 2F9 – OTHER

4.29.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	2F7: Semiconductor Manufacture 2F8: Electrical Insulation 2F9: Training Shoes One Component Foams	OTH, T1, T2, T3	CS, OTH
Gases Reported	HFCs, PFCs, SF_6		
Key Categories (Trends)	None identified		
Key Categories (Level)	Industrial Processes - HFCs		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	All relevant emissions from OTs and CDs are included within the UK totals for this sector. Emissions are calculated by scaling emissions from the UK model using a suitable scaling factor (population, GDP etc.).		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

In the CRF, emissions in 2F9 are presented in two separate categories. One Component Foams, and Semiconductors, Electrical and Production of Trainers. Emissions from Semiconductors, Electrical and Production of Trainers have been combined in order to preserve the confidentiality of estimates of emissions of SF_6 and PFCs used in training shoes.

One Component Foams:
One Component Foams (OCFs) are used by tradesmen (and in the home improvement sector, to a lesser extent) to mount doors and windows and to insulate different types of open joints and gaps. When used as an OCF propellant, HFC (134a, 152a) is blended with various flammable gases. HFC escapes from the foam on application, leaving small residues, which remain in the hardened foam for up to a year. These products are not manufactured in the UK, although they are imported. The use of HFCs in OCFs has been banned under the EC Regulation on fluorinated greenhouse gases (EC 842/2006) from July 4th 2008, except for where their use is safety critical.

Semiconductor manufacture:
PFCs and SF_6 are released from activities in this source sector.

The electronics industry is one of the largest sources of PFC emissions in the UK. The main uses of PFCs are as follows:

- Cleaning of chambers used for chemical vapour deposition (CVD) processes;
- Dry plasma etching;
- Vapour phase soldering and vapour phase blanketing;
- Leak testing of hermetically sealed components; and
- Cooling liquids, e.g. in supercomputers or radar systems.

In addition SF_6 is used in etching processes for polysilicon and nitrite surfaces, and there is some usage of CHF_3 and NF_3. The first two of these processes (cleaning and etching during semiconductor manufacture) account for the majority of emissions from the sector, with cleaning accounting for around 70% and etching 30%.

Electrical Equipment:
SF_6 is released from activities in this source sector.

Sulphur hexafluoride has been used in high and medium voltage switch gear and transformers since the mid-1960s. The physical properties of the gas make it uniquely effective as an arc-quenching medium and as an insulator. Consequently it has gradually replaced equipment using older technologies, namely oil filled and air blast equipment. Currently, there are no alternative fluids that have the same properties as SF_6.

Production of Trainers:
A sports goods manufacturer selling shoes in the UK used SF6 as a cushioning material in a range of training shoes from 1990 to 2003. Prior to 1990, the manufacturer used perfluoroethane (a PFC) for cushioning. SF6 is well suited to this application because it is chemically and biologically inert and its high molecular weight means it cannot easily diffuse across membranes. This means the gas is not released until the training shoe is destroyed at the end of its useful life.

The manufacturer committed itself to eliminating SF6 from its training shoes by 30 June 2003 – a goal which was achieved. It had originally planned to replace all SF6 applications with nitrogen-filled cushioning but technical difficulties mean it had to switch temporarily to perfluoropropane (a PFC) in some high-performance applications. The use of F gases in footwear was banned in 2006 by the F gas Regulation and discussions with the manufacturer have confirmed that they are no longer using PFCs or SF_6.

Cushioning units typically outlast the lifetime of the training shoe because the rate of diffusion of SF6 is so slow. In the UK, training shoes are generally sent to landfill at the end of their useful lives, where any SF6 or PFC will eventually leak to the atmosphere.

4.29.2 Methodological Issues

One Component Foams:
The method of calculation is an IPCC Tier 2 method.

UK estimates of emissions from this source were based on a European evaluation of emissions from this sector (Harnisch and Schwarz, 2003), subsequently disaggregated by GDP to provide a top-down UK estimate.

It has been very difficult to establish the exact size of the UK import market and, therefore, hard to generate an accurate estimate of emissions from the use of this product.

Harnisch and Schwarz (2003) estimated EU emissions from OCFs as follows:

- 1996: 4,000 kt CO_2 equivalent per annum (3100 tonnes of HFC 134a)
- 2000: 1,700 kt CO_2 equivalent per annum (1200 tonnes of HFC 134a; 1000 tonnes of HFC 152a)
- 2010: 2,320 kt CO_2 equivalent per annum (1636 tonnes of HFC 134a; 1364 tonnes of HFC 152a)

Emissions in tonnes of CO_2 equivalent have reduced between 1996 and 2000 due to the use of HFCs with lower GWP values, and the manufacture of cans containing less HFC. In 2000, 23 million OCF cans that contained HFCs were sold in Germany while 7 million where sold to the rest of the EU market. An assumption has been made that Germany accounts for 77% of the total EU emission. Out of the remaining 23%, the UK accounts for 24%, based on a percentage of total EU GDP (excluding Germany). This is equivalent to 1.68 million cans.

The estimates of HFCs assume that the ban on F gas use in one component foams (banned from July 2008 under the F Gas regulations) has been successful, and this success has been confirmed with the UK Defra F-gas regulation team. Therefore no emissions occur from 2009 onwards.

Semiconductor manufacture:
The methodology used to estimates emissions corresponds to an IPCC Tier 1 method.

Emissions of PFC and SF_6 emissions from electronics are based on data supplied by UK MEAC – the UK Microelectronics Environmental Advisory Committee (in conjunction with the UK DTI). UK MEAC gave PFC consumption for the UK electronics sector based on purchases of PFCs as reported by individual companies. Emissions were then calculated using the IPCC Tier 1 methodology, which subtracts the amount of gas left in the shipping container (the “heel” amount, 10%), the amount converted to other products (between 20% and 80% depending on the gas) and the amount fed to abatement. The general equation used to calculate the emissions is given later in this section.

The estimates of HFC and SF_6 emissions are based on consumption data (purchases) from 2001, which were supplied by the UK MEAC / DTI. The data supplied were the purchases, used by the semiconductor industry, of SF_6 and NF_3, and the following PFC species: C_2F_6, CF_4, CHF_3, C_3F_8, and C_4F_8. Estimates of PFC and SF_6 consumptions in the years before and after 2001 are made from assumptions about the annual growth rates, and the annual rate of change of usage per unit consumption. Both these sets of data are supplied by MEAC.

Estimates of emissions in the time series are based on i) the consumption of gases in sector and ii) assumptions about growth rate in sector, gas use and abatement.

Emissions of PFCs for previous years were extrapolated backwards (to 1990) assuming an annual 15% growth in the production of semiconductors in the UK up until 1999. A sharp

decline in growth is then assumed in 2001, and from 2006 onwards, a growth of 10% is assumed and this growth then declines slowly from 2013 onwards.

An annual increase in the amount of PFCs used per unit production is assumed. PFC specific usage data are used to estimate emissions. Across the time series C_2F_6 consumption dominates total PFC consumption. This figure is 3% from 1990 to 1996, as production methods required more PFCs for finer and more complex etching processes. A gradual decrease to 0% in 1999 and –1% in 2000 is assumed as measures to reduce use of PFCs begin to be implemented. The figure then declines to -2% until 2004, and then declines further to -8% until 2010 and is assumed constant at -1% into the future.

Emission estimates of PFC and SF_6 emissions were calculated using modification of an equation provided by the World Semiconductor Council (WSC). For example, the equation below is used for the estimation of CF_4.

$$\text{Emissions for PFC}_i = \text{PFCi}*(1-h)[(1-C_i)(1-A_i)*GWP_i + B_i*GWP_{CF4}*(1-A_{CF4})]$$

h = fraction of gas_i remaining in container (heel)
PFC_i = purchases of gas_i = kgs_i
kgs_i = mass of gas_i purchased
GWP_i = 100 yr global warming potential of gas_i
C_i = average utilization factor of gas_i (average for all etch and CVD processes)
= 1-EF_i
EF_i = average emission factor of gas_i (average for all etch and CVD processes)
B_i = mass of CF_4 created per unit mass of PFC_i transformed
A_i = fraction of PFC_i destroyed by abatement = $a_{i,j}*V_a$
A_{CF4} = fraction of PFC_i converted to CF_4 and destroyed by abatement = $a_{CF4}*V_a$
$a_{i,j}$ = average destruction efficiency of abatement $tool_j$ for gas_i
a_{CF4} = average destruction efficiency of abatement $tool_j$ for CF_4
V_a = fraction of gas_i that is fed into the abatement tools

Emissions of PFCs and SF_6 from semiconductor manufacturing are combined with emissions from training shoes and electrical insulation in source category 2F9 for reasons of commercial confidentiality.

A full description of the emissions and associated methodology used is contained in AEA (2004). The estimates were reviewed in 2008 and last updated in 2004.

Table 4-36 Key assumptions used to estimate emissions from semiconductor manufacture

	1990-1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2009	2010	2011	2015	2020-2025
Annual growth in UK semiconductor production	15%	15%	15%	15%	16%	-39%	0%	0%	0%	5%	10%	10%	10%	7%	5%
Annual rate of change of usage per unit consumption															
CF_4	3%	2%	1%	0%	-1%	-1%	-2%	-2%	-2%	-8%	-8%	-8%	-1%	-1%	-1%
C_2F_6	3%	2%	1%	0%	-1%	-1%	-2%	-2%	-2%	-8%	-8%	-8%	-1%	-1%	-1%
C_3F_8	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	-1%	-1%	-1%
C_4F_8	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	-1%	-1%	-1%
CHF_3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SF_6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
NF_3	0%	0%	0%	0%	0%	2%	3%	5%	5%	5%	5%	5%	0%	0%	0%
Consumption, kg*															
CF_4		3640	4269	4959	5752	3,474	3404	3336	3270	3158	3313	3352	3651	4859	
C_2F_6		14882	17456	20275	23519	14,203	13919	13641	13368	12914	13545	13707	14927	19867	
C_3F_8		582	669	770	893	550	556	561	567	601	925	1027	1119	1489	
C_4F_8		37	43	49	57	35	35	36	36	38	59	65	71	95	
CHF_3		2166	2491	2865	3324	2,027	2027	2027	2027	2129	3117	3428	3771	5225	
SF_6		1379	1586	1824	2116	1,291	1291	1291	1291	1355	1984	2183	2401	3327	
NF_3		2459	2828	3252	3772	2,301	2301	2301	2301	2416	3313	3891	4281	5931	
Fraction fed to abatement															
CF_4	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	45%	50%	50%
C_2F_6	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	45%	50%	50%
C_3F_8	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	45%	50%	50%
C_4F_8	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	45%	50%	50%
CHF_3	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	45%	50%	50%
SF_6	0%	0%	0%	0%	0%	0%	0%	0%	10%	15%	35%	40%	45%	50%	50%
NF_3	90%	90%	90%	90%	90%	90%	90%	90%	95%	100%	100%	100%	100%	100%	100%

*Derived from 2001 data, working backwards or forwards from 2001 consumption using annual growth rate and rate of change of consumption per unit production for appropriate year.

Electrical Equipment:
The method used to estimate emissions is an IPCC Tier 2 method, based on a fluid bank model.

BEAMA (representing equipment manufacturers) and the Electricity Association (representing electricity transmission and distribution) were able to provide limited data on SF_6 bank sizes. The Electricity Association (for electricity transmission and distribution) provided SF_6 bank size data for 1995 and 2000.

In order to estimate a historical time series and projections, these emission estimates together with fluid bank estimates provided by the utilities were extrapolated using following the method originally applied by (March 1999). This involved estimating leakage factors based on the collected data and using the March model to estimate the time series. Emissions prior to 1995 used the March SF_6 consumption data to extrapolate backwards to 1990 from the 1995 estimates. Projections were made using the model based on an assumed increase in the fluid bank to 2025 based on advice provided by the utilities. Future leakage rates and recovery rates were estimated assuming improved equipment specification and improving repair and recovery practices.

The key assumptions used in the emissions model for this work are provided below.

Table 4-37 Key assumptions used to estimate emissions from electrical equipment

	Parameter	1990	1995	2000	2005	2010	2011	2015	2020
Activity data	Total SF_6 used for manufacture (tonnes)	140	115	70	63	63	63	63	61
	Net proportion exported (%)	40%	40%	40%	40%	40%	40%	40%	40%
	Decommissioned (tonnes)	20	20	40	32	32	32	32	32
	Bank size in 1990 (tonnes)	232	-	-	-	-		-	-
Emission factors	PM	0.08	0.08	0.08	0.072	0.064	0.064	0.064	0.064
	PL	0.0436	0.0436	0.038	0.032	0.031	0.031	0.029	0.028
See note below	D	0.20	0.20	0.05	0.04	0.04	0.04	0.04	0.04

Note: PM, PL and D are expressed as factors and not percentages in the table above

Emissions of SF_6 from electrical equipment (insulation in electrical transmission and distribution – e.g. switchgear) are combined with emissions from training shoes and semiconductor manufacture in source category 2F9 for reasons of commercial confidentiality.

A full description of the emissions and associated methodology used is contained in AEA (2004). The estimates were reviewed in 2008 and last updated in 2004.

Production of Trainers:
Estimates of emissions from sports-shoes were based on a bottom-up Tier 2 estimate, using activity data supplied in confidence by the manufacturer.

Emissions from these sectors have been combined for reasons of commercial confidentiality. A full description of the emissions and associated methodology used is contained in AEA (2004) and AEA (2008).

Emissions of PFCs and SF_6 from training shoes are combined with emissions from semiconductor manufacturing in source category 2F8b for reasons of commercial confidentiality.

Overseas Territories and Crown Dependencies
Speciated emissions are now reported under 2F9. Emission estimates from the UK GHGI were scaled by the GDP or population of each territory. This is the first submission in which speciated f-gas emissions have been reported for the overseas territories and crown dependencies.

4.29.3 Uncertainties and Time-Series Consistency

Estimates of emissions are based on very limited data and are therefore uncertain.

One Component Foams:
Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2004), based on an understanding of the uncertainties within the sector and from discussion with industry. Emissions from this sector are estimated to fall within an uncertainty range of 10-25%. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

2F9 – Semiconductors, Electrical and Production of Trainers:
Estimates of the uncertainties associated with time-series data for this sector were made in AEA (2004) and reviewed in AEA (2008), based on an understanding of the uncertainties within the sector and from discussion with industry. Estimated uncertainties in individual sectors: sports-shoes: +/- 20-50%, electronics +/- 30-60%, and electrical transmission and distribution +/- 20%. Uncertainty data from this study have been used in the uncertainty analysis presented in **Annex 7**.

4.29.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**. Details of verification of emissions are given in **Annex 10**.

Trilateral F-gas Peer Review
A trilateral meeting of F-gas sector experts from the UK, Austria and Germany was held in Vienna, February 2011. Although not a formal review, each country reviewed the completeness, consistency and transparency of the parts of the NIRs reporting F-gases. Some of the improvements that could be made to the transparency and completeness of the UK NIR identified in that review have been incorporated in this NIR, and others will be considered for future implementation.

4.29.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 4-38** below. For information on the magnitude of recalculations to Source Category 2F9, see **Section 10**.

Table 4-38 2F9 - Other use of F-gases - Source specific recalculations since previous submission

IPCC Category	Source Name	Activity Name	2011 submission		2012 submission		Units	Comment/Justification
			1990	2009	1990	2009		
2F9	Semiconductors, electrical and sporting goods	SF_6	0.604	0.559	0.604	0.559	Mt CO_2 equivalent	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory.
2F9	Overseas Territories and Crown Dependencies	HFCs	0.000	0.086	0.000	0.000	Mt CO_2 equivalent	Estimates now integrated with appropriate reporting categories, and reported as individual HFC species
2F9	Overseas Territories and Crown Dependencies	SF_6	0.000	0.001	0.000	0.000	Mt CO_2 equivalent	Estimates now integrated with appropriate reporting categories.

4.29.6 Source Specific Planned Improvements

Activity data and emission factors will be kept under review.

5 Solvent and Other Product Use (CRF Sector 3)

5.1 OVERVIEW OF SECTOR

IPCC Categories Included	3A Paint Application 3B Degreasing & Dry Cleaning 3C Chemical Products, Manufacture & Processing 3D Other
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	Emissions from the Overseas Territories and Crown Dependencies are included within the CRF submission under 3D5 other non-specified and are scaled, based on UK emissions.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

5.2 SOURCE CATEGORY 3A – PAINT APPLICATION

5.2.1 Source Category Description

Emissions sources	3A: Decorative paint (retail decorative) Decorative paint (trade decorative) Industrial Coatings (automotive) Industrial Coatings (agriculture & construction) Industrial Coatings (aircraft) Industrial Coatings (Drum) Industrial Coatings (coil coating) Industrial Coatings (commercial vehicles) Industrial Coatings (high performance) Industrial Coatings (marine) Industrial Coatings (metal and plastic) Industrial Coatings (metal packaging) Industrial Coatings (vehicle refinishing) Industrial Coatings (wood)
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	Emissions from the Overseas Territories and Crown Dependencies are included within the CRF submission under 3D5 other non-specified and are scaled, based on UK

	emissions.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

Emissions of solvents from the use of both industrial and decorative paints are reported under CRF source category 3A. Both types of paint are further sub-divided in the GHGI:

Table 5-1 Paints and their applications in the UK

Type of paint	Application
Decorative paint:	
Retail decorative	'DIY' decorative coatings mainly sold directly to the public
Trade decorative	'Professional' decorative coatings mainly sold to decorating contractors
Industrial coatings:	
ACE	Coatings for agricultural, construction and earthmoving equipment
Aircraft	Coatings for aircraft & aircraft components
Coil	Coatings for steel and aluminium coil
Commercial vehicles	Coatings for new, non-mass produced vehicles
Drum	Coatings for new and reclaimed metal drums
High performance	Coatings for large structures such as bridges, offshore installations etc.
Marine	Coatings for the exteriors and interiors of ships and yachts including both new and old vessels
Metal and plastic	Coatings for metal and plastic substrates not covered elsewhere
Metal packaging	Coatings for food and beverage cans and other small metal packaging
OEM	Coatings for new mass-produced road vehicles
Vehicle refinishing	Coatings for the refinishing of road vehicles
Wood	Coatings for wooden substrates

5.2.2 Methodological Issues

Emission estimates for most types of coatings are based on annual consumption data and emission factors provided by the British Coatings Federation (BCF, 2012). Emission estimates for drum coatings, metal packaging and OEM coatings are estimated instead using a combination of consumption data and emission factors and estimates made on a plant by plant basis using information supplied by the Metal Packaging Manufacturers Association (MPMA, 2000) and the regulators of individual sites.

5.2.3 Uncertainties and Time- Series Consistency

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Approach 1 (error propagation) or Tier 2 uncertainty analysis.

The data used to estimate emissions from paint application are mostly provided by the British Coating Federation (BCF) and the data are thought to be consistent. Estimates for the drum coating, car coating, and metal packaging coating sectors are based on emissions data collected from regulators for the latter part of the time series with extrapolation to earlier years on the basis of BCF coating consumption data. This extrapolation is thought unlikely to introduce significant problems with the accuracy of estimates.

5.2.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

5.2.5 Source Specific Recalculations

No direct greenhouse gases are reported in this section and no major methodological changes have been made this year

5.2.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

5.3 SOURCE CATEGORY 3B – DEGREASING & DRY CLEANING

5.3.1 Source Category Description

Emissions sources	3B: Dry Cleaning Surface Cleaning Leather Degreasing
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	Emissions from the Overseas Territories and Crown Dependencies are included within the CRF submission under 3D5 other non-specified and are scaled, based on UK emissions.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

This sector covers the use, predominantly of chlorinated solvents, for cleaning and degreasing of surfaces, including degreasing of sheepskins and the use of tetrachloroethene for dry cleaning of clothes and textiles.

Chlorinated solvents, including trichloroethene, tetrachloroethene and dichloromethane are widely used in industry to clean metallic, plastic and other surfaces, often using the process of vapour degreasing. Objects to be cleaned are suspended above boiling solvent. Solvent vapour condenses on the object and removes grease and other surface contamination. Cooling tubes at the top of the tank minimise emissions but some solvent is emitted. Cold

cleaning is also used with objects being dipped in cold solvent and larger objects may be hand cleaned with solvent-soaked cloths. Historically, 1,1,1-trichloroethane was also used as a cleaning solvent but this was prohibited due to this solvent's contribution to ozone depletion and use ceased by 1999. Hydrocarbons and oxygenated solvents are also used as cleaning solvents, generally being used for hand cleaning or cold cleaning of objects.

Sheepskins must be degreased due to their high fat content before they can be converted into leather. Degreasing can be done using either hydrocarbon or chlorinated solvents.

Dry cleaning involves the use of tetrachloroethene to clean clothes and textiles in special equipment. The solvent is largely recovered and recycled within the machine but emissions do occur, especially in older 'open' machines, where the final drying stage involves venting of solvent-laden vapour to atmosphere.

5.3.2 Methodological Issues

Emission estimates for surface cleaning processes are based on estimates of annual consumption and emission factors. Consumption estimates are based on data from UK industry sources and UK and European trade associations, together with some published data. Some extrapolation of data is necessary, using Index of Output data produced annually by the Office for National Statistics (ONS, 2012), although this is not expected to introduce significant uncertainty into the estimates. Emission factors assume that all hydrocarbon and oxygenated solvent is emitted, while emission factors for chlorinated solvents are lower, reflecting the fact that some solvent is sent for disposal rather than emitted.

Emission estimates for dry cleaning are based on estimates of solvent consumption by the sector. Industry-sourced data are available for some years and estimates for the remaining years are based on a model of the sector, which takes account of changes in the UK population and the numbers of machines of different types and with different emission levels.

Emission estimates for leather degreasing are based on a single estimate of solvent use extrapolated to all years using the Index of Output for the leather industry, which is produced annually by the ONS.

5.3.3 Uncertainties and Time-Series Consistency

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Approach 1 (error propagation) or Tier 2 uncertainty analysis.

The time series for degreasing emissions uses a consistent methodology, although the activity data used are not of uniform quality for each year, some extrapolation of data being required. This extrapolation is not thought likely to introduce significant problems with the accuracy of estimates. Although perhaps more uncertain than estimates for 3A and 3C, the estimates for source category are still expected to be good.

5.3.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

5.3.5 Source Specific Recalculations

No direct greenhouse gases are reported in this section and no major methodological changes have been made this year

5.3.6 Source Specific Planned Improvements

Emission factors and activity data will be kept under review.

5.4 SOURCE CATEGORY 3C – CHEMICAL PRODUCTS, MANUFACTURE AND PROCESSING

5.4.1 Source Category Description

Emissions sources	3C: Coating Manufacture (paint) Coating Manufacture (ink) Coating Manufacture (glue) Film Coating Leather coating Other Rubber Products Tyre Manufacture Textile Coating
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	Emissions from the Overseas Territories and Crown Dependencies are included within the CRF submission under 3D5 other non-specified and are scaled, based on UK emissions.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

This sector includes the manufacture of coatings, the coating of films, leather, paper and textiles, and the use of solvents in the manufacture of tyres and other rubber products.

Coating manufacture includes the manufacture of paints, inks, and adhesives, plus specialist coatings for films, leather, paper and textiles.

Film coating includes the manufacture of photographic film, data storage films, hot stamping films and other specialist products. Processes manufacturing hot stamping films can use particularly large quantities of solvents.

Leather is generally coated with products that are waterborne, although more solvent borne coatings were used historically. Coatings are used to provide protection or to enhance the appearance by improving colour or glossiness.

Textile coating processes can include the application of waterproof or fire-proof coatings to textiles and coating of textiles with rubber.

Solvents are used in the manufacture of tyres and other rubber products such as hose, belting and sports goods. The solvent is used for cleaning and also to increase the tackiness of the rubber during joining operations.

5.4.2 Methodological Issues

Emission estimates for coating of film, leather, and textiles as well as estimates for tyre manufacture are based on plant-by-plant emission estimates, made on the basis of information available from regulators.

Emissions from coating manufacture are calculated from the solvent contained in coatings produced in the UK, by assuming that an additional 2.5% of solvent was lost during manufacture.

Emissions from the manufacture of rubber goods other than tyres are based on solvent consumption estimates provided by the British Rubber Manufacturers Association (BRMA, 2001), which are extrapolated to other years on the basis of the Index of Output figures for the rubber industry which are published each year by the ONS.

5.4.3 Uncertainties and Time Series Consistency

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Approach 1 (error propagation) or Tier 2 uncertainty analysis.

Estimates for sources covered by source category 3C are estimating using a consistent methodology with relatively little extrapolation of data. As with the estimates for source categories 3A and 3B, extrapolation of data is not thought likely to introduce significant problems with the accuracy of estimates.

5.4.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

5.4.5 Source-specific recalculations

No direct greenhouse gases are reported in this section and no major methodological changes have been made this year

5.4.6 Source Specific Planned Improvements

Emission factors and activity data for the category will be kept under review.

5.5 SOURCE CATEGORY 3D - OTHER

5.5.1 Source Category Description

Emissions sources	3D: Aerosols (Car care, Cosmetics & toiletries, household products) Agrochemicals Use Industrial Adhesives Paper Coating Printing Other Solvent Use Non Aerosol Products (household, automotive, cosmetics & toiletries, domestic adhesives, paint thinner) Seed Oil Extraction Wood Impregnation
Gases Reported	NMVOC
Overseas Territories and Crown Dependencies Reporting	Emissions from the Overseas Territories and Crown Dependencies are included within the CRF submission under 3D5 other non-specified and are scaled, based on UK emissions.
Completeness	Emissions of CO_2 for this sector are currently not estimated although emissions from this source are considered to be very small. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	No major improvements

This category covers a diverse group of sources including paper coating, printing processes, adhesives use, seed oil extraction, wood impregnation, agrochemicals use, aerosols, consumer products and miscellaneous solvent use.

Paper coating processes include solvent used in the manufacture of wallpapers, together with coating of other specialist paper products such as vehicle air filters or colour cards.

Printing processes differ in their requirement for solvent-borne inks and chemicals. Most solvent use occurs from the printing of flexible packaging using flexography and rotogravure printing with solvent-borne inks. Publication gravure printing for magazines and catalogues etc. also uses high solvent inks. Heatset web offset printing, coldset web offset, and sheetfed offset, used for printing magazines, newspapers and other publications, employ paste inks that contain high boiling point hydrocarbons which are driven off and burnt in the case of heatset web offset or absorb into the printed substrate in the case of the other two processes. Offset presses may use solvents in the 'damping solutions', which are used to ensure accurate reproduction of the image. Letterpress printing also uses paste inks that dry by adsorption and is little used now. Paper & board packaging are printed using flexography, rotogravure and offset although, unlike flexible packaging, the flexographic and gravure inks used are generally waterborne. Screen printing, used for high quality colour printing such as art reproduction, textile printing and point of sale printing can use either water or solvent-based inks.

Other, specialist printing processes include printing of roll labels and printing of securities both of which use a variety of printing techniques including offset, letterpress, copperplate (a form of gravure printing with paste inks), flexography, and screen printing. Solvent-borne varnishes may be applied over some printed materials.

Adhesives are used by many industries, although solvent-borne adhesives are becoming increasingly confined to a small number of industry sectors. Construction and pressure-sensitive tapes and labels are the largest users of solvent-borne adhesives. Other sectors include footwear, abrasives, and some furniture manufacture.

Seed oil extraction involves the use of hexane to extract vegetable oil from rape and other seed oils. The solvent is recovered and reused in the process.

Solvents are used in some wood preservatives, although consumption has fallen markedly in the last ten years. Emissions from use of creosote, which does not contain solvent, are also reported under 3D.

Agrochemicals can be supplied in many forms including solid or solutions and some are dissolved in organic solvents, which are emitted when the agrochemical is applied.

Aerosols use organic chemicals both as propellants and as solvents. All use of volatile organic materials in aerosols is reported under CRF source category 3D. Non-aerosol consumer products which contain or can contain significant levels of solvents include fragrances, nail varnish and nail varnish remover, hair styling products, slow release air fresheners, polishes, degreasers, screen wash, and de-icers.

Miscellaneous solvent use includes solvent usage not covered elsewhere and, current, little information is available on the types of uses included. However, it will include applications such as pharmaceutical processes, acetylene storage, flavour extraction, foam blowing, production of asbestos-based products, oil-field chemicals and foundry chemicals.

Nitrous oxide emissions from anaesthesia use are reported as NE since the data are not available and emissions are believed to be small.

5.5.2 Methodological issues

Emission estimates are based on one of three approaches:

1. Estimates are made based on activity data and emission factors supplied by industry sources (printing processes, consumer products, wood preservation)
2. Estimates are made for each process in a sector based on information provided by regulators or process operators (seed oil extraction, pressure sensitive tapes, paper coating)
3. Estimates are based on estimates of solvent consumption supplied by industry sources (adhesives, aerosols, agrochemicals, miscellaneous solvent use).

All overseas territories and crown dependencies emissions arising from Solvents are reported under 3D5. Emission estimates from the UK GHGI were scaled by a territory-specific indicator. Relevant indicators include territory population, GDP, number of cars and number of households. The indicators for each activity were chosen using expert judgement and were dependent on the information available for each territory.

5.5.3 Uncertainties and time-series consistency

This source does not affect the overall total or trend in UK emissions of direct greenhouse gases and is not included in the Approach 1 (error propagation) or Tier 2 uncertainty analysis.

Estimates for sources covered by source category 3D are estimating using a consistent methodology with relatively little extrapolation of data. Some extrapolation of activity data is required for some sources included in source category 3D as this will limit the accuracy of emission estimates for these sources e.g. industrial adhesives, other solvent use. Other sources included in 3D, including emission estimates for printing and paper coating are likely to be comparable in quality to the estimates for paint application or chemical products (source categories 3A and 3C). Overall, however, the estimate for source category 3D is likely to be more uncertain than those for 3A, 3B and 3C.

5.5.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

5.5.5 Source-specific recalculations

No direct greenhouse gases are reported in this section and no major methodological changes have been made this year

5.5.6 Source-specific planned improvements

Emission factors and activity data for the category will be kept under review.

6 Agriculture (CRF sector 4)

6.1 OVERVIEW OF SECTOR

IPCC Categories Included	4A: Enteric Fermentation 4B: Manure Management 4D: Agricultural Soils 4F: Field Burning of Agricultural Residues 4G: Other
Gases Reported	CH_4, N_2O, NO_x, CO, NMVOC, SO_2
Key Categories (Trends)	Agricultural Soils – N_2O Manure Management – N_2O
Key Categories (Level)	Agricultural Soils – N_2O Manure Management – N_2O Enteric Fermentation in Domestic Livestock – CH_4
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Emissions for OTs and CDs are included for enteric fermentation animal wastes and agricultural soils.
Completeness	No emissions are reported for categories 4D3 and 4D4 because no emissions have been identified. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	Update to histosols area following UNFCCC recommendation

The agriculture sector has the second largest contribution to total GHG emissions in the UK, after the energy sector. It contributes approximately 8% to the total emissions. The emissions from this sector have shown an overall decrease of 20% since 1990, reflecting trends in livestock numbers and emissions from fertiliser application.

Figure 6-1 Breakdown of total GHG emissions in the Agriculture sector in 2011

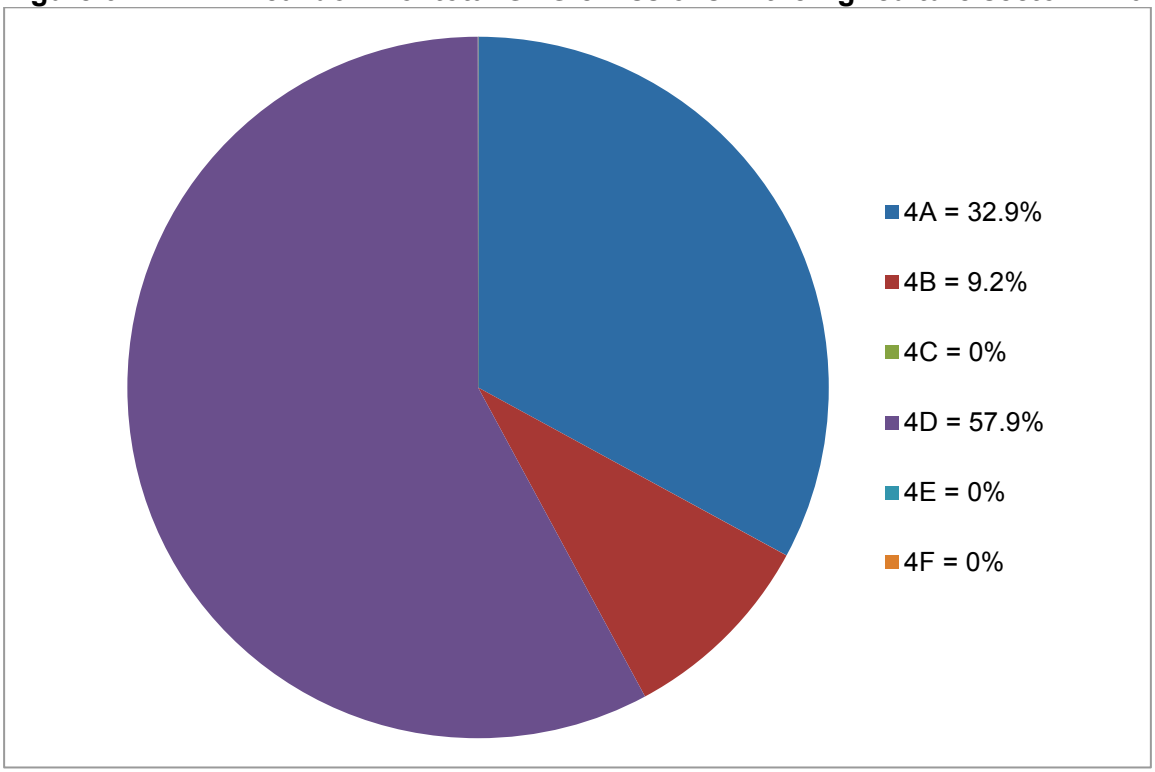
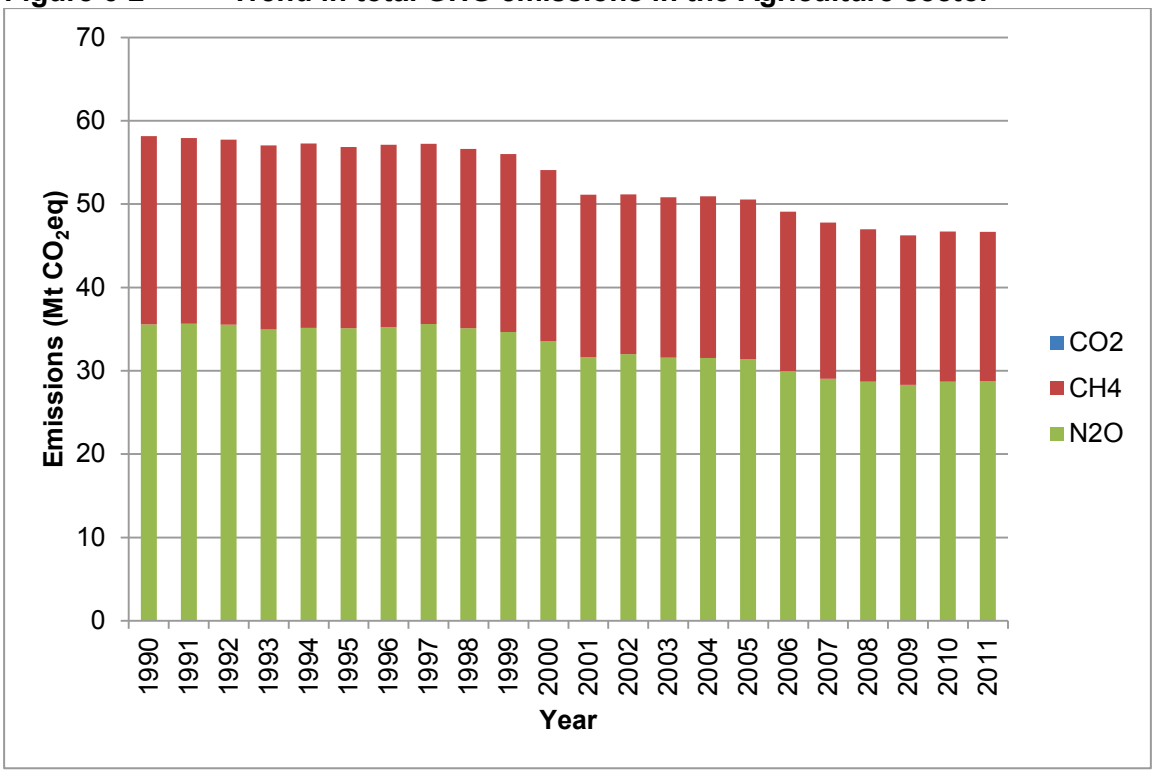


Figure 6-2 Trend in total GHG emissions in the Agriculture sector



6.2 SOURCE CATEGORY 4A – ENTERIC FERMENTATION

6.2.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	4A1: Dairy Cattle Enteric Other Cattle Enteric 4A3: Sheep Enteric 4A4: Goats Enteric 4A6: Horses Enteric 4A8: Pigs Enteric 4A10: Deer Enteric	T2 T2 T1 T1 T1 T1 T1	D D CS D D D CS
Gases Reported	CH_4		
Key Categories (Trends)	None identified		
Key Categories (Level)	Enteric Fermentation in Domestic Livestock – CH_4		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	A separate category for all OTs and CDs livestock is used in the CRF (4A10). IPCC default EFs are applied to animal numbers. Tables of animal numbers used in calculations can be found in **Annex 3.9.**		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Revision to feed digestibility for cattle. Lamb lifespan revised following UNFCCC review recommendation.		

Methane is produced in herbivores as a by-product of enteric fermentation. Enteric fermentation is a digestive process whereby carbohydrates are broken down by micro-organisms into simple molecules. Both ruminant animals (e.g. cattle and sheep), and non-ruminant animals (e.g. pigs and horses) produce CH_4, although ruminants are the largest source per unit of feed intake.

6.2.2 Methodological issues

Detailed information on activity data and emissions factors can be found in **Annex 3**, **Section A3.6.1**.

Emissions from enteric fermentation are calculated from detailed animal livestock population data collected in the June Agricultural Census and the appropriate emission factors (see **Table A 3.5.3** in **Annex 3**). Livestock population data are reported annually as statistical outputs of the four Devolved Administrations of the UK (i.e. England, Wales, Scotland and Northern Ireland), based on the annual June Agricultural Survey for each country[32]. These data are summed to provide UK population data for the livestock categories and

[32] **England:** http://www.defra.gov.uk/statistics/foodfarm/landuselivestock/junesurvey/junesurveyresults/
Scotland: http://www.scotland.gov.uk/Publications/2011/09/27083355/0
Wales: John Bleasdale, Welsh Government
Northern Ireland: and Paul Caskie, Department of Agriculture and Rural Development for Northern Ireland (DARDNI)

subcategories as used in the inventory compilation (See **Tables A3.6.1** and **A3.6.2** in **Annex 3**). Data for earlier years are often revised so information was taken from the England and the Devolved Administrations' agricultural statistics databases.

Apart from dairy and beef cows, lambs and deer, the methane emission factors are IPCC Tier 1 defaults (IPCC, 1997) and do not change from year to year.

6.2.2.1 Dairy cows

The dairy cattle emission factors (for dairy cows only) are estimated following the IPCC Tier 2 procedure (IPCC, 2000), using country-specific data for dairy cow live weight, milk yield, milk fat content, feed digestibility and activity (proportion of the year spent grazing) and vary from year to year (see **Tables A3.6.4** and **A3.6.5** in **Annex 3**). For dairy cows, the calculations are based on the population of the 'dairy breeding herd' which is defined as dairy cows over two years of age with offspring. Dairy cows live weights are derived from slaughter weight data, provided by Defra[33], based on a slaughter weight to live weight ratio of 0.48. There has been a linear increase in reported slaughter weights since 1990, with the exception of the period 1997 to 2005 during which period one of the measures introduced by the EU commission to control the exposure of humans to BSE (the 'Over 30 Month scheme') produced anomalies in the data series. Dairy cow live weights for this period were therefore derived by interpolation using the linear regression fitted to the periods before and after these dates; see **Tables A3.6.3**, **A3.6.4** and **A3.6.5** in **Annex 3.** Details of the method used to estimate live weight from slaughter weights can be found below. Milk yield is obtained from the Defra website[34].

A country-specific value (75%) for the digestibility of feed (DE), expressed as a percentage of the gross energy, for dairy cows is used. This value is considerably higher than the IPCC (1997) default value for Western Europe of 60%, but is based on typical diets for cows over the lactating and non-lactating period, combining forage and concentrates, with energy values for the various feeds according to MAFF (1990) (Bruce Cottrill, ADAS, pers. comm.).

The diet characteristics are derived in two components, that fed as concentrates (for which robust industry data in terms of amounts fed exist) and that fed as forage (estimated from the dietary requirement and the knowledge of concentrate use). For the typical dairy cow, the forage component represents 62% of annual dietary dry matter intake. The forage component is assumed to consist of fresh grass (grazed), grass silage and maize silage, in the ratio 4:4:1, with a weighted average DE value of approximately 72%. The constituents of the concentrate feed are assumed to be barley grain, sugar beet pulp (molassed), wheat feed, wheat grain, rapeseed meal, soya bean meal and sunflower meal, with a weighted average DE value of approximately 82%. The overall weighted average DE value for the diet is therefore estimated as 75%.

6.2.2.2 Beef cows

A Tier 2 methodology is used for the calculation of the enteric emissions from beef cows, but a time series of cattle weights is not available, and so a constant weight of 500 kg has been assumed. The main parameters involved in the calculation of the emissions factors for beef are shown in **Table A 3.5.6** (**Annex 3**).

[33] http://www.defra.gov.uk/statistics/foodfarm/food/slaughter/

[34] http://www.defra.gov.uk/statistics/files/defra-stats-foodfarm-crosscutting-auk-auk2011-120709.pdf , (Chapter 5 – Commodities, Table 5.17 Milk; UK).

6.2.2.3 Other cattle

A Tier 2 methodology is used for the calculation of the emissions from other cattle but live weight is not changed from year to year (**Table A 3.5.6** in **Annex 3**). A number of additional cattle categories have been introduced to allow for more accurate source apportionment of emissions to the 'Dairy' and 'Beef' sectors. Cattle now comprise the following eight groups: dairy cows, beef cows, dairy heifers, beef heifers, dairy replacements > 1 year, beef all other > 1 year, dairy calves < 1 year, beef calves < 1 year.

6.2.2.4 Sheep

The UK sheep production sector has a complex structure, with many different breeds of sheep and a range of hill, upland and lowland rearing and finishing systems. The UK is currently undertaking a programme of work to improve methodology for calculating emissions from this sector, which will include derivation of monthly sheep and lamb population models and country-specific emission factors. The current approach is to assume the IPCC Tier 1 default emission factor for enteric fermentation for all mature sheep (> 1 year old). Lambs have a lower average live weight than mature sheep and the majority have a lifespan of less than 12 months, and should therefore be associated with a lower emission factor than mature sheep. The UK therefore uses a country-specific emission factor for enteric fermentation for lambs at 40% of that of an adult sheep (Sneath et al. 1997) together with a reduction factor reflecting the reduced lifespan of lambs. The average lifespan of lambs is estimated by Wheeler et al. (2012) as 8.1 months. The category 'other sheep' are largely barren ewes that will be slaughtered at some time during the year. These are therefore assumed to be alive for 6 months of the year, which is reflected in the emission calculation rather than the emission factor. These emission factors are assumed constant over the entire time series.

6.2.2.5 Deer

The UK emission factor for deer is based on Sneath et al. (1997).

6.2.2.6 Overseas Territories and Crown Dependencies

Emission estimates were compiled by Aether using animal numbers were sourced from the territories directly or from the FAO and can be found in **Annex 3.9**. IPCC default emission factors were applied to these data.

6.2.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.2.1** and **Table A7.2.2**, provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from animal population data and appropriate emission factors. The animal population data are collected in the June Agricultural Census, published annually by the devolved administrations (i.e. England, Wales, Scotland and Northern Ireland). These are long running publications and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

6.2.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.9**.

6.2.5 Source-specific recalculations

Details of and justifications for recalculations to activity data and to emission factors are given in **Table 6-1** and **Table 6-2**, respectively. For information on the magnitude of recalculations to Source Category 4A, see **Section 10**.

Dairy cow feed digestibility was corrected from 73.588 to 75%, according to information from Bruce Cottrill (ADAS, pers. comm.). This was applied to the entire time series.

Dairy cow live weight anomalies (due to the Over Thirty Month Scheme) for the years 1997-2005 have been updated. Live weights for this period were derived by interpolation using the linear regression fitted to the periods before and after these dates.

The enteric emission factor for lambs has been revised. Previously lambs were assumed to have a 6 month lifespan, this has been revised to 8.1 months (ADAS report by Wheeler et al. (2012), *"More robust evidence on the average age of UK lambs at slaughter"*). The report is based on survey data for data one year only, but the revision has been applied to the whole time series.

For the Cayman Islands, there have been significant changes to the livestock numbers since the previous submission. This was due to sourcing additional activity data and improved calculations to ensure the consistency of the time series. For example, the emission estimates from goats increased 10 fold and emissions from swine changed by -31% to 85% across the time series. These changes resulted in a varied change in the overall enteric fermentation emission estimates: -9% in 2000 to 18% in 2010. The magnitudes of these revisions are an indication of the uncertainties that can accompany datasets from small island locations.

Table 6-1 4A Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
4.A.1	Enteric fermentation - Cattle	653.68	563.14	647.49	557.49	kt	Feed digestibility revised from 73.588 to 75%. Updated provisional cow milk yield data for 2010. Dairy cow live weights updated for the years 1997-2005 (In country review recommendation).
4.A.3	Enteric fermentation – Sheep (Lambs)	209.34	147.73	222.02	156.46	kt	Lamb lifespan revised from 6 months to 8.1 months (In country review recommendation)

Table 6-2 4A Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
4.A.1	Enteric fermentation - Cattle	89.0	111.5	86.8	108.4	kg CH_4 $head^{-1}$ yr^{-1}	Feed digestibility revised from 73.588 to 75%. Updated provisional cow milk yield data for 2010. Dairy cow live weights updated for the years 1997-2005 (In country review recommendation).
4.A.3	Enteric fermentation – Lambs	1.6	1.6	2.2	2.2	kg CH_4 $head^{-1}$ yr^{-1}	Lamb lifespan revised from 6 months to 8.1 months (factor quoted assumes animal lives for 8.1 months) (In country review recommendation)

6.2.6 Source-specific planned improvements

Emission factors and activity data will be kept under review. The Tier 2 structure will be incorporated for all key animal categories (cattle, pigs and sheep) and calculations included when activity data are available.

6.3 SOURCE CATEGORY 4B – MANURE MANAGEMENT

6.3.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	4B1: Dairy Cattle Wastes	T2	CS, D
	Other Cattle Wastes	T2	CS, D
	4B3: Sheep Wastes	T2	CS, D
	4B4: Goats Wastes	T2	CS, D
	4B6: Horses Wastes	T2	CS, D
	4B8: Pigs Wastes	T2	CS, D
	4B9: Broilers Wastes	T2	CS, D
	Laying Hens Wastes	T2	CS, D
	Other Poultry Wastes	T2	CS, D
	4B10: Deer Wastes	T2	CS, D
Gases Reported	CH_4, N_2O		
Key Categories (Trends)	Manure Management – N_2O		
Key Categories (Level)	Manure Management – N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	It was not possible to introduce a new category in which to put emissions of N_2O from manure from the OTs and CDs into Sector 4B. A separate category was therefore included in Sector 4G - Other. A timeseries of UK EFs are applied to animal numbers.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Revision to feed digestibility for cattle. Lamb lifespan revised following UNFCCC review recommendation.		

This category reports emissions of CH_4 from animal manures as well as N_2O emissions from their manures arising during its storage.

6.3.2 Methodological issues

6.3.2.1 Methane emissions from animal manures

Methane is produced from the decomposition of manure under anaerobic conditions. When manure is stored or treated as a liquid in a lagoon, pond or tank it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid or when it is deposited on pastures, it tends to decompose aerobically and little or no methane is produced. Hence the system of manure management used affects emission

rates. Emissions of methane from animal manures are calculated from livestock population data provided by the devolved administrations as described in **Section 6.2.2**. The emission factors are listed in **Table A 3.5.3**. **Table A 3.5.7** shows the methane conversion factors assumed for the different systems.

The emission factors for manure management are calculated following IPCC Tier 2 methodology using default IPCC data for volatile solids (VS) and methane producing potential (B_o) parameters for each livestock type (except for dairy and beef cows, where a Tier 2 calculation (IPCC 2000, Equation 4.16) is used to determine VS, and deer where no IPCC data are available), country-specific data for the proportion of manure from each livestock type managed according to the different animal waste management systems (AWMS) and IPCC default methane conversion factors for the different AWMS (IPCC 2000, Equation 4.17). The emission factors are listed in **Table A 3.5.3 (Annex 3)**. **Table A 3.5.7 (Annex 3)** shows the methane conversion factors assumed for the different systems.

Emission factors and underlying data for dairy cows, beef cows and other cattle are given in **Tables A 3.6.3**. to **A 3.6.6 in Annex 3**.

Country-specific data on the proportion of manure managed in the different AWMS data derive from a number of sources, including published ad-hoc surveys (e.g. Smith et al., 2000a, 2001b, 2001c; Sheppard 1998, 2002; Webb et al., 2001) and, more recently, relevant data from the Farm Practices Surveys for England and a time series is included to reflect changes in practice over time (data for 2011 are given in **Table A 3.5.9** in **Annex 3**). We now include a time series for AWMS.

6.3.2.2 Nitrous Oxide emissions from Animal Waste Management Systems

Animals are assumed not to give rise to nitrous oxide emissions directly, but emissions will arise from N excreted by livestock. Emissions from manures during storage are calculated for a number of animal waste management systems (AWMS) defined by IPCC. Calculation follows IPCC (1997) (equation 2, p 4.98) for each livestock category and subcategory, using country-specific data for nitrogen excretion by the different livestock types and for the proportion of manure managed according to the different AWMS, and default IPCC emission factors for the different AWMS (IPCC, 2000). Country-specific values for nitrogen excretion per head for the different livestock types were derived from the report of Defra project WT0715NVZ (Defra, 2006) with interpretation by Cottrill and Smith (ADAS) (**Table A 3.5.8 in Annex 3**).

The conversion of excreted N into N_2O emissions is determined by the type of manure management system used. The distribution of waste management systems for each animal type ($AWMS_{(T)}$) is given in **Table A 3.5.9** in **Annex 3**. Emissions from poultry are calculated following IPCC (2000) where manure is allocated to poultry with or without bedding, but reported as AWMS 'Other'.

Emissions from the following AWMS are reported under the Manure Management IPCC category:

- Flushing anaerobic lagoons. These are assumed not to be in use in the UK.
- Liquid systems (i.e. slurry)
- Solid storage and dry lot (including farm-yard manure). Only dry lot is used in the UK.
- Other systems (poultry manure without bedding and poultry manure with bedding (poultry litter); IPCC (2000)

According to IPCC (1997) guidelines and IPCC GPG (2000), the following AWMS are reported in the Agricultural Soils category:

- All animal manures and slurries applied to soils
- Pasture range and paddock

Emissions from the combustion of poultry litter for electricity generation are reported under power stations. Emissions occurring during storage of poultry litter that will later be used for energy generation are included in the agricultural inventory.

Table A 3.5.10 gives the N_2O emission factor for each animal waste management system ($EF3_{(AWMS)}$). These are expressed as the emission of N_2O-N per mass of excreted N processed by the waste management system.

6.3.2.3 Emissions in the Overseas Territories and Crown Dependencies

Animal numbers are sourced from the territories directly or from the FAO and can be found in **Annex 3.9**. Estimates for CH_4 emissions from manure management are calculated using IPCC default emission factors. N_2O estimates are calculated using UK GHGI emission factors. Emission estimates were compiled by Aether and Ricardo-AEA.

6.3.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from livestock population data and appropriate emission factors. The livestock population data are collected in the June Agricultural Census, published annually by the devolved administrations (i.e. England, Wales, Scotland and Northern Ireland). These are long running publications and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

6.3.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures which are discussed in **Section 6.9.**

6.3.5 Source-specific recalculations

Details of and justifications for recalculations to activity data and to emission factors are given in **Table 6-3** and **Table 6-4** respectively. For information on the magnitude of recalculations to Source Category 4B, see **Section 10**.

Dairy cow feed digestibility was corrected from 73.588 to 75%, according to information from Bruce Cottrill (pers comm.). This was applied to the entire time series.

The ash value for manure from all cattle has been updated from 7.90 to 8.0% to agree with the IPCC default (IPCC, 2000). This change also encompassed a correction to the beef cattle manure ash value which was resulting in an overestimation of methane emission from this source (a value of 3.04% was previously used in error).

Dairy cow live weight anomalies (due to the Over Thirty Month rule) for the years 1997-2005 have been updated. Live weights for this period were derived by interpolation using the linear regression fitted to the periods before and after these dates.

The waste CH_4 emission factor for lambs has been revised due to:

- The lamb EF should be 40% of the adult sheep EF of 0.19, this had not been applied.
- Previously lambs were assumed to have a 6 month lifespan, this has been revised to 8.1 months (ADAS report by Wheeler et al. (2012), More robust evidence on the average age of UK lambs at slaughter). The report is based on survey data for data one year only, but the revision has been applied to the whole time series.

The lowland/upland split for N excretion from ewes and lambs has been removed. N excretion for ewes has been revised to 9 kg/year (from 10.5/9.9 kg/year for lowland/upland ewes) and for lambs to 2.4 kg/year (from 0.6/0.7 kg/6 months for lowland/upland lambs) according to Smith & Frost (2000). The N excretion values were revised because the value for ewes was found to include lambs and the value for lambs was not applicable to the lambs whole lifespan (only after weaning), thus both values were inaccurate. Other sheep are assumed to live 6 months of the year, and lambs are now assumed to have a lifespan 8.1 months (Wheeler et al. 2012).

There have been significant changes to the livestock numbers for the OTs and CDs since the previous submission due to improved calculations to ensure the consistency of the time series. There was a decrease in estimated emissions from Montserrat “other manure” due to a change in the emission factor which is now consistent with the UK GHGI. Updates to the interpolation methods used for CH_4 swine manure emissions led to a decrease of emissions of up to 28% for Montserrat although this difference was negligible in the UK totals.

Table 6-3 4B Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
4.B.1	Methane emissions from manure management - Cattle	83.59	84.69	78.57	79.45	kt	Feed digestibility revised from 73.588 to 75%. Ash value for cattle manure has been updated from 7.90 to 8.0%. Correction of an error in the beef cattle manure ash value. Updated provisional cow milk yield data for 2010. Dairy cow live weights updated for the years 1997-2005 (In country review recommendation).
4.B.3	Methane emissions from manure management - Lambs	6.11	4.29	5.16	3.63	kt	Correction to the lamb waste EF (lamb EF should be 40% of the adult sheep EF; this had not been applied). Lamb lifespan revised from 6 to 8.1 months (In country review recommendation).
4.B.12-14	Nitrous oxide emissions from manure management - AWMS	6.32	5.38	6.32	5.37	kt	Removed the upland lowland split for N excretion from ewes and lambs. (In country review recommendation). Updated provisional cow milk yield data for 2010. Corrected error for nitrous oxide emissions from horses (data for 2011 was incorrect).

Table 6-4 4B Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
4.B.1	Methane emissions from manure management – Dairy cattle	21.7	33.8	20.0	31.1	kg CH_4/hd/yr	Ash value for cattle manure has been updated from 7.90 to 8.0%. Feed digestibility revised from 73.588 to 75%. Updated provisional cow milk yield data for 2010. Dairy cow live weights updated for the years 1997-2005 (In country review recommendation).
4.B.1	Methane emissions from manure management – Beef cows	2.60	2.60	2.47	2.47	kg CH_4/hd/yr	Correction of an error in the beef cattle manure ash value.
4.B.3	Methane emissions from manure management - Lambs	0.19	0.19	0.05	0.05	kg CH_4/hd/yr	Correction to the lamb waste EF (lamb EF should be 40% of the adult sheep EF; this had not been applied). . Lamb lifespan revised from 6 to 8.1 months (In country review recommendation)

6.3.6 Source-specific planned improvements

Emission factors and activity data will be kept under review including the use of more detailed emission factors and activity data to allow estimation of the effect of future mitigation policies.

6.4 SOURCE CATEGORY 4C – RICE CULTIVATION

This source is not relevant in the UK.

6.5 SOURCE CATEGORY 4D – AGRICULTURAL SOILS

6.5.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	4D1: Agricultural Soils: Direct Soil Emissions	T1, T1a	D
	4D2: Agricultural Soils: Animal Emissions	T2	CS
	4D4: Agricultural Soils: Indirect Emissions	T1	D
Gases Reported	N_2O		
Key Categories (Trends)	Agricultural Soils – N_2O		
Key Categories (Level)	Agricultural Soils – N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions included under 4D4 'other' within the CRF. These estimates use tier 1 methodology.		
Completeness	No emissions are reported for categories 4D3 and 4D4 because no emissions have been identified. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	The area of cultivated histosols has been updated to agree with that reported under LULUCF. Reported value of N input from application of synthetic and organic fertiliser and sewage sludge is now corrected for volatilisation. Inclusion of emissions from OTs and CDs following UNFCCC review recommendations.		

Direct emissions of nitrous oxide from agricultural soils are estimated using the IPCC recommended methodology (IPCC, 1997) but incorporating some UK specific parameters. The IPCC method involves estimating contributions from:

(i) The use of inorganic fertilizer
(ii) Biological fixation of nitrogen by crops
(iii) Crop residues returned to soils

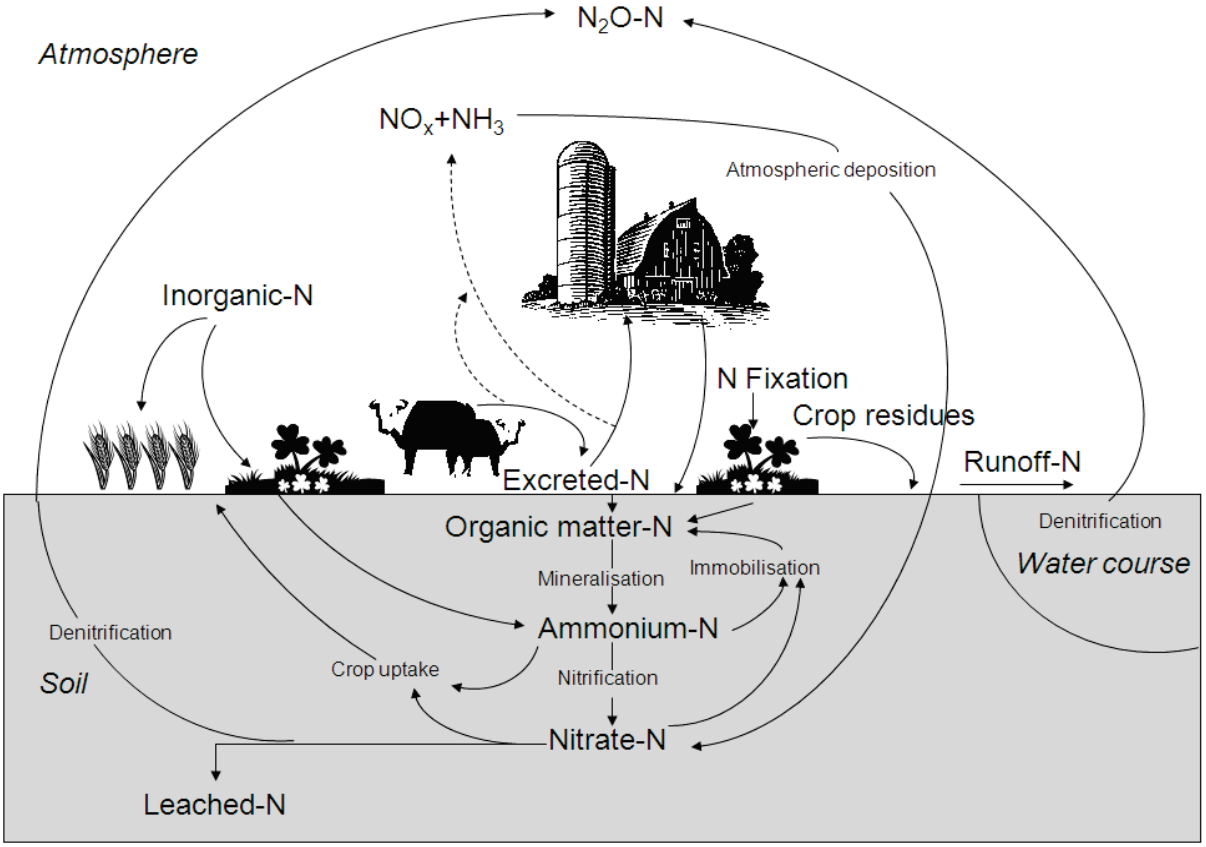
(iv) Cultivation of histosols (organic soils)
(v) Manure deposited by grazing animals in the field
(vi) Application of livestock manures to land
(vii) Application of sewage sludge to land
(viii) Emissions from improved grassland

In addition to these, the following indirect emission sources are estimated:

(ix) Emission of N_2O from atmospheric deposition of agricultural NO_x and NH_3
(x) Emission of N_2O from leaching and run-off of agricultural nitrate

Descriptions of the methods used are described in **Section 6.5.2**. A nitrogen cycle is included to describe the sources of N_2O from agriculture (**Figure 6-3**).

Figure 6-3 Simplified nitrogen cycle highlighting the steps involved in the production of N_2O from agriculture.



6.5.2 Methodological issues

6.5.2.1 Inorganic Fertiliser

Emissions from the application of inorganic fertilizer are calculated using the IPCC (2000) Tier 1 methodology (equation 4.20) and IPCC default emission factors.

Annual consumption of synthetic fertilizer is estimated based on crop areas from the England and the Devolved Administrations[35] as shown in **Table A 3.5.11** (**Annex 3**). **Table A 3.5.12** shows the trend in areas and fertiliser N application rates for the major crop categories over the period 1990-2011.

6.5.2.2 Biological Fixation of Nitrogen by crops

Emissions of nitrous oxide from the biological fixation of nitrogen by crops are calculated using the IPCC (2000) methodology (equation 4.20) and IPCC default emission factors.

The data for the ratio residue/crop are default values found under Agricultural Soils or derived from Table 4.17 in Field Burning of Agricultural Residues (IPCC, 1997). Crop production data were provided by Tom Johnson, DEFRA (England & Wales), Gregor Berry, The Scottish Government and Conor McCormack, DARDNI. The fraction of dry mass for the crops considered is given in **Table A 3.5.13 (Annex 3)**.

6.5.2.3 Crop Residues

Emissions of nitrous oxide from the ploughing in of crop residues are calculated using the IPCC (1997) methodology and IPCC default emission factors using equation 4.29 of the IPCC GPG (2000).

Production data of crops are provided by Tom Johnson, DEFRA (England & Wales), Gregor Berry, The Scottish Government and Conor McCormack, DARDNI and are shown in **Table A 3.5.14**. The dry mass fraction of crops and residue fraction are given in **Table A 3.5.13**. Field burning has largely ceased in the UK since 1993. For years prior to 1993, field-burning data were taken from the annual MAFF Straw Disposal Survey (MAFF, 1995). Dry matter contents of crops are derived from Burton (1982), Nix (1997), PGRE (1998), BLRA (1998).

6.5.2.4 Histosols

Emissions from histosols are estimated using the IPCC (2000) default factor of 8 kg N_2O-N/ha/yr. The area of cultivated histosols is estimated at 1500 km^2 (as in **Section A3.6.3.4**).

6.5.2.5 Grazing Animals

Emissions from manure deposited by grazing animals are reported under agricultural soils by IPCC. The method of calculation is the same as that for AWMS (**Section 6.3.2.2**), using the IPCC default emission factors for pasture range and paddock and country specific data for the fraction of livestock N excreted and deposited onto soil during grazing. The latter UK specific value is much larger than the IPCC default value (0.23), as cattle in particular spend more time grazing at pasture in the UK than is the case in many other countries (**Section A3.6.2.1 Table A 3.5.5**).

6.5.2.6 Organic Fertilizers

Following the IPCC guidance, emissions from animal manures and slurries used as organic fertilizers are reported under agricultural soils using IPCC default emission factors and country-specific data for the amount of manure nitrogen applied to the land.

[35] **England**: http://www.defra.gov.uk/statistics/foodfarm/landuselivestock/junesurvey/junesurveyresults/
Scotland: http://www.scotland.gov.uk/Publications/2011/09/27083355/0,
Wales: John Bleasdale, Welsh Government and Paul Caskie,
Northern Ireland: DARDNI). and fertilizer application rates (BSFP, 2012 and Paul Caskie, DARDNI)

The summation is for all animal types and manure previously stored in categories defined as a) liquid, b) solid storage and dry lot and c) other (poultry manure without bedding and poultry manure with bedding (litter)).

The UK follows the IPCC (2000) methodology. This assumes that 20% of the total manure N applied to soil volatilises as NO_x and NH_3 and therefore does not contribute to direct N_2O emissions. For daily spreading of manure and application of previously stored manures to land, the emission is given by equations 4.20 and 4.23 of IPCC GPG (2000). The summation is for all animal types and manure that is daily spread or previously stored in categories defined as a) liquid, b) solid storage and dry lot and c) other (poultry manure without bedding or poultry manure with bedding (litter)).

6.5.2.7 Application of sewage sludge to land

Following the IPCC 2000 GPG methodology, emissions from sewage sludge used as fertilizer are reported under agricultural soils. The calculation involves estimating the amount of nitrogen contained per dry matter unit of sludge that is applied to land and applying IPCC emission factors (see **Table A 3.5.15)**. Data sources for the annual production of sewage sludge (as dry matter) were obtained from OFWAT, the Water Commissioner for Scotland and the Northern Ireland regulator, UREGNI. The amounts for the missing years were derived by interpolation/extrapolation of the available data.

The UK follows the IPCC (2000) methodology (equation 4.20). This assumes that 20% of the total sludge N applied to soil volatilises as NO_x and NH_3 and therefore does not contribute to direct N_2O emissions.

6.5.2.8 Emissions from improved grassland

The total N_2O emission reported also includes a contribution from nitrogen fixation on improved grassland. For this source the calculation of the emission requires estimating the amount of N that is fixed and then the IPCC emission factor is applied to this value. The amount of nitrogen fixed is derived using a country specific fixation rate of 4 kg N/ha/year (Lord, 1997).

6.5.2.9 Atmospheric deposition of NO_X and NH_3

Indirect emissions of N_2O from the atmospheric deposition of ammonia and NO_x are estimated according to the IPCC (2000). The sources of NH_3 and NO_x considered are synthetic fertiliser application, animal manures applied as fertiliser and sewage sludge applied to soils. The contribution from synthetic fertilisers is given by equations 4.30, 4.31 of the IPCC GPG (2000).

The method used corrects for the N content of manures used as fuel.

6.5.2.10 Leaching and runoff

Indirect emissions of N_2O from leaching and runoff are estimated according the IPCC using equations 4.34, 4.35, 4.36 from IPCC GPG (2000). The sources of nitrogen considered, are synthetic fertiliser application and animal manures applied as fertiliser and sewage sludge applied to soils.

The method used corrects for the N content of manures used as fuel (poultry litter incineration).

6.5.2.11 Overseas Territories and Crown Dependencies

Emission estimates from agricultural soils have been estimated for the first time for all overseas territories and crown dependencies. The Tier 1 methodology from the IPCC Guidelines was applied. Livestock data were provided by the territories or sourced from FAO; the quantity of synthetic fertiliser applied and crop production data were obtained from FAO and Defra. All of these data can be found in **Annex 3.9**. Emission factors were taken from the IPCC guidelines and Western European emission factors were applied to all CDs (Isle of Man, Guernsey and Jersey) whilst Latin American emission factors were applied to all OTs (Cayman Islands, Falkland Islands, Montserrat and Bermuda). There is no commercial agricultural activity in Gibraltar therefore no emissions are reported.. Emission estimates were compiled by Aether and Ricardo-AEA.

6.5.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, provides estimates of uncertainty according to IPCC source category.

Emissions are calculated from a range of activity data and appropriate emission factors (see **Section A3.6.3**). Emissions of N_2O from the use of fertilizers are important in this source category. The annual consumption of synthetic fertilizer is estimated based on crop areas (crop area data reported annually by the Devolved Administrations) and fertilizer application rates (reported annually in the British Survey of Fertiliser Practice). These are both long running datasets and the compilers of the activity data strive to use consistent methods to produce the activity data. The time-series consistency of these activity data is very good due to the continuity in data provided.

6.5.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.9.**

6.5.5 Source-specific recalculations

Details of and justifications for recalculations to activity data are given in **Table 6-5**. For information on the magnitude of recalculations to Source Category 4D, see **Section 10**.

The lowland/upland split for N excretion from ewes and lambs has been removed. N excretion for ewes has been revised to 9 kg/year (from 10.5/9.9 kg/year for lowland/upland ewes) and for lambs to 2.4 kg/year (from 0.6/0.7 kg/6 months for lowland/upland lambs) according to Smith & Frost (2000). The N excretion values were revised because the value for ewes was found to include lambs and the value for lambs was not applicable to the lambs whole lifespan (only after weaning); thus both values were inaccurate. Other sheep are assumed to live 6 months of the year, and lambs are now assumed to have a lifespan 8.1 months (Wheeler et al. 2012).

The area of cultivated histosols has been updated to agree with that reported under LULUCF. Area increased from 392 km^2 to 1500 km^2 (as in Table A 3.6.26; total area of peat 150,000 ha).

Reported value of N input from application of synthetic and organic fertiliser and sewage sludge is now corrected for volatilisation (previously reported as the total with no correction).
The fraction of livestock N excretion in excrements burned for fuel is now expressed as a fraction of all livestock groups N (previously expressed as a fraction of poultry N).

Table 6-5 4D Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
4.D.1.1	Direct soil emissions - Synthetic fertilisers	27.71	19.82	28.11	20.35	kt	The 2011 submission fertiliser N rate for rye, triticale and durum wheat and maize for Scotland and NI had been omitted for 2010. Crop area and fertiliser N rate time series' updated.
4.D.1.2	Direct soil emissions - Spreading animal manures on land	8.36	6.47	8.36	6.46	kt	Removed the upland lowland split for N excretion from ewes and lambs (In country review recommendation). Updated provisional cow milk yield data for 2010.
4.D.1.3	Direct soil emissions – N fixing crops	0.85	0.70	0.85	0.68	kt	Crop production time series updated.
4.D.1.4	Direct soil emission - Crop residue	7.02	8.06	7.06	8.09	kt	Oats and rye DM corrected for Scotland Updated crop production data.
4.D.1.5	Direct soil emission – Cultivation of histosols	0.49	0.49	1.89	1.89	kt	Histosols UK area updated from 392 km^2 to 1500 km^2 (In country review recommendation)
4.D.2	Pasture, Range and Paddock Manure	21.33	17.84	21.20	17.73	kt	Removed upland lowland split for N excretion from ewes and lambs. (In country review recommendation).
4.D.3.1	Indirect Emissions - Atmospheric deposition	6.33	5.00	6.35	5.00	kt	The 2010 fertiliser N rate for rye, triticale and durum wheat and maize for Scotland and NI had been omitted. Crop area and fertiliser N rate time series' updated. Removed upland lowland split for N excretion from ewes and lambs. (In country review recommendation). Provisional sewage sludge data for the years 2008 to 2010 replaced with actual values.
4.D.3.2	Indirect Emissions – Nitrogen Leaching and Run-off	32.96	25.36	33.17	25.52	kt	The 2010 fertiliser N rate for rye, triticale and durum wheat and maize for Scotland and NI had been omitted. Crop area and fertiliser N rate time series updated. Removed upland lowland split for N excretion from ewes and lambs. (In country review recommendation). Provisional sewage sludge data for the years 2008 to 2010 replaced with actual values.
4.D.4	Other – Improved Grassland	0.56	0.56	0.57	0.57	kt	Crop area time series updated.
4.D.4	Other – Municipal sewage sludge applied to fields	0.28	0.80	0.28	0.61	kt	Provisional sewage sludge data for the years 2008 to 2010 replaced with actual values.

6.5.6 Source-specific planned improvements

Emission factors and activity data will be kept under review. UK emission factors are currently under review for:

- EF1, emission factor for direct soil emissions; from a literature review and a field measurement programme.
- EF3, emission factor from manure management systems); from a literature review and a field measurement programme and,
- EF5, nitrogen leaching/runoff factor; from a field measurement programme

The UK is improving the link between the NH_3 and GHG inventories, and incorporating NO_x in a study (desk/experimental) which will review the current value of 20% of N lost as NH_3 and NO_x.

6.6 SOURCE CATEGORY 4E – PRESCRIBED BURNING OF SAVANNAS

This source is not relevant in the UK.

6.7 SOURCE CATEGORY 4F – FIELD BURNING OF AGRICULTURAL RESIDUES

6.7.1 Source category description

Emissions sources	Source included	Method	Emission Factors
	4F1: Barley Residue Wheat Residue Oats Residue 4F5: Linseed Residue	T1 T1 T1 T1	D D D D
Gases Reported	CH_4, N_2O, NO_x, CO, NMVOC, SO_2		
Key Categories (Trends)	Agricultural Soils – N_2O Manure Management – N_2O		
Key Categories (Level)	Agricultural Soils – N_2O Manure Management – N_2O Enteric Fermentation in Domestic Livestock – CH_4		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	No data available for this source. No emissions reported		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	No major improvements		

This sector covers the emissions of non-CO_2 greenhouse gases from the burning (in the field) of crop residue and other agricultural waste on site.

6.7.2 Methodological issues

The National Atmospheric Emissions Inventory reports emissions from field burning under the category agricultural incineration. The estimates are derived from emission factors calculated according to IPCC (1997) and from USEPA (1997) shown in **Table A 3.5.16**.

The estimates of the masses of residue burnt of barley, oats, wheat and linseed are based on crop production data (Tom Johnson, DEFRA (England & Wales), Gregor Berry, The Scottish Government and Conor McCormack, DARDNI) and data on the fraction of crop residues burnt (MAFF, 1995; ADAS, 1995). Field burning ceased in 1993 in England and Wales. Burning in Scotland and Northern Ireland is considered negligible, so no estimates are reported from 1993 onwards. The carbon dioxide emissions are not estimated because these are part of the annual carbon cycle.

6.7.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.2.1** and **Table A7.2.2**, provides estimates of uncertainty according to IPCC source category.

Field burning ceased in 1994, and emissions are reported as zero after this date.

6.7.4 Source-specific QA/QC and verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 6.9.**

6.7.5 Source-specific recalculations

Details of and justifications for recalculations to data are given in **Table 6-6** below. For information on the magnitude of recalculations to Source Category 4F, see **Section 10**.
For oats, barley and linseed replaced N-C ratio value of 0.012 (value for wheat) with the correct default value of 0.015 (IPCC 1997).

Table 6-6 4F Source specific recalculations to data since previous submission

IPCC Category	Source Name	2011 submission 1990	2011 submission 2009	2012 submission 1990	2012 submission 2009	Units	Comment/Justification
4.F	Nitrous oxide	0.25	0	0.26	0	kt	Oats and rye DM corrected for Scotland and N-C ratio for oats, barley and linseed updated from 0.012 to 0.015 Updated crop production data
4.F	Methane	12.64	0	12.66	0	kt	N-C ratio for oats, barley and linseed updated from 0.012 to 0.015 Updated crop production data

6.7.6 Source-specific planned improvements

No improvements are planned.

6.8 SOURCE CATEGORY 4G - OTHER

There are no emissions reported in the UK under this category.

6.9 GENERAL COMMENTS ON QA/QC

The livestock activity data used for constructing the inventory are supplied annually from the June census[36], who follow documented QA procedures. Activity data on mineral fertiliser are calculated using application rates from Defra's annual British Survey of Fertiliser Practice (BSFP) multiplied by crop areas from the June Census. Data from the June Census, in the form of *.PDF files, can be downloaded from the Devolved Administrations websites and incorporated into inventory spreadsheets without the need for manual data entry, eliminating the need for double entry procedures. Annual comparisons of emission factors and other coefficients used are made by contractors compiling the inventory on behalf of Defra and by Defra itself. Any changes are documented in the spreadsheet and in the accompanying chapter of the National Inventory Report. Hardcopies of the submitted inventories, associated emails and copies of activity data are filed in Government secure files adhering to Government rules on document management.

Defra contractors who work on compiling the agricultural inventory, Rothamsted Research, operate strict internal quality assurance systems with a management team for each project overseen by an experienced scientist with expertise in the topic area. A Laboratory Notebook scheme provides quality control through all phases of the research and these are archived in secure facilities at the end of the project. All experiments are approved by a consultant statistician at each of the planning, data analysis and interpretation and synthesis stages. A range of internal checks exists to ensure that projects run to schedule, and internal and external (*viz*. visiting group procedures, etc.) reviews ensure the quality of the outputs.

The data for livestock numbers and crop areas are supplemented by data provided by the Centre for Ecology and Hydrology (U. Dragotsis) for England, Scotland and Northern Ireland but not Wales. The livestock and crop area data are also used to generate the NH_3 inventory.

[36] **England:** http://www.defra.gov.uk/statistics/foodfarm/landuselivestock/junesurvey/junesurveyresults/
Scotland: http://www.scotland.gov.uk/Publications/2011/09/27083355/0,
Wales: John Bleasdale, Welsh Government
Northern Ireland: Paul Caskie, DARDNI

7 Land-Use, Land Use Change and Forestry (CRF Sector 5)

7.1 OVERVIEW OF SECTOR

IPCC Categories Included	5A: Forest Land 5B: Cropland 5C: Grassland 5D: Wetlands 5E: Settlements 5G: Other (Harvested wood products)
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO
Key Categories (Trends)	None identified
Key Categories (Level)	5A LULUCF – CO_2 5B LULUCF – CO_2 5C LULUCF – CO_2 5E LULUCF – CO_2
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	Inclusion of new activities (N_2O from forest drainage and biomass burning emissions from non-forest wildfires)

CRF Sector 5 includes carbon stock changes, emissions of greenhouse gases (CO_2, CH_4 and N_2O) by sources and removals of CO_2 by sinks from land use, land use change and forestry activities. Removals of carbon dioxide are conventionally presented as negative quantities. The sector has been a net sink since 2001, with a net removal in 2011 of -3.22 Mt CO_2 equivalent (**Figure 7-1**), or -3.31 Mt CO_2 equivalent when the Overseas Territories and Crown Dependencies (OTs/CDs) are included.

Figure 7-1 LULUCF emissions and removals from the UK 1990-2011 by category

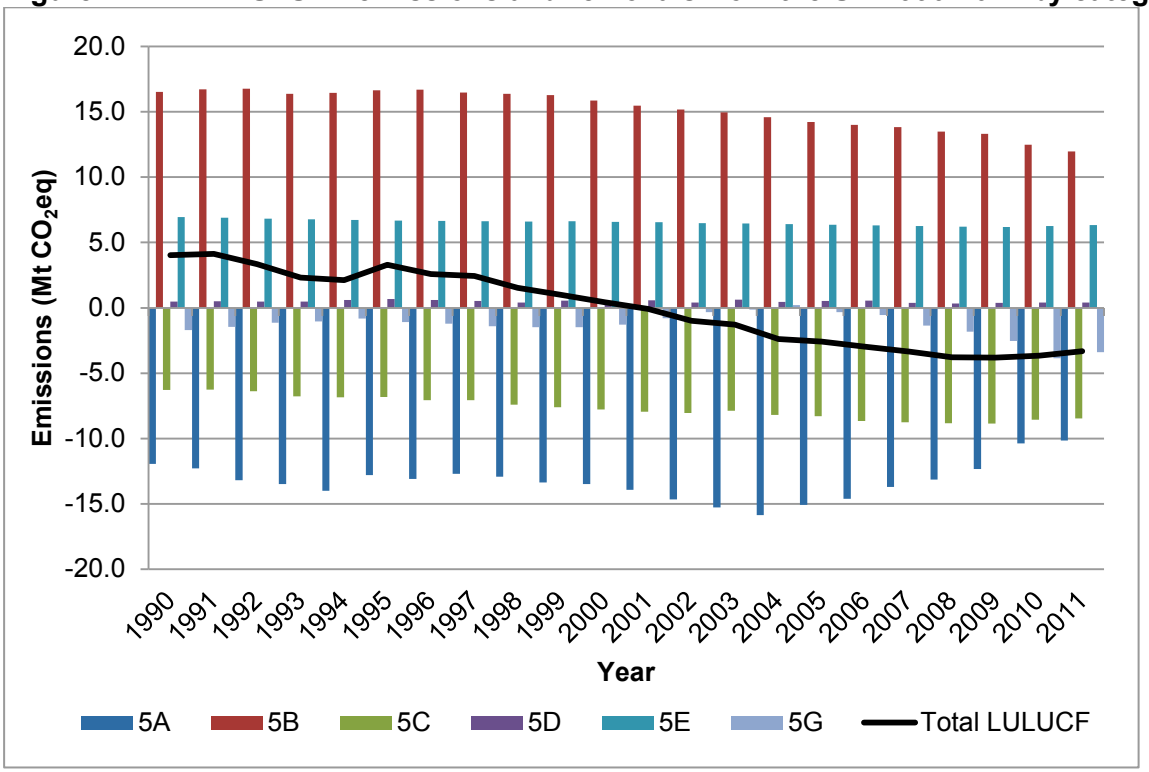
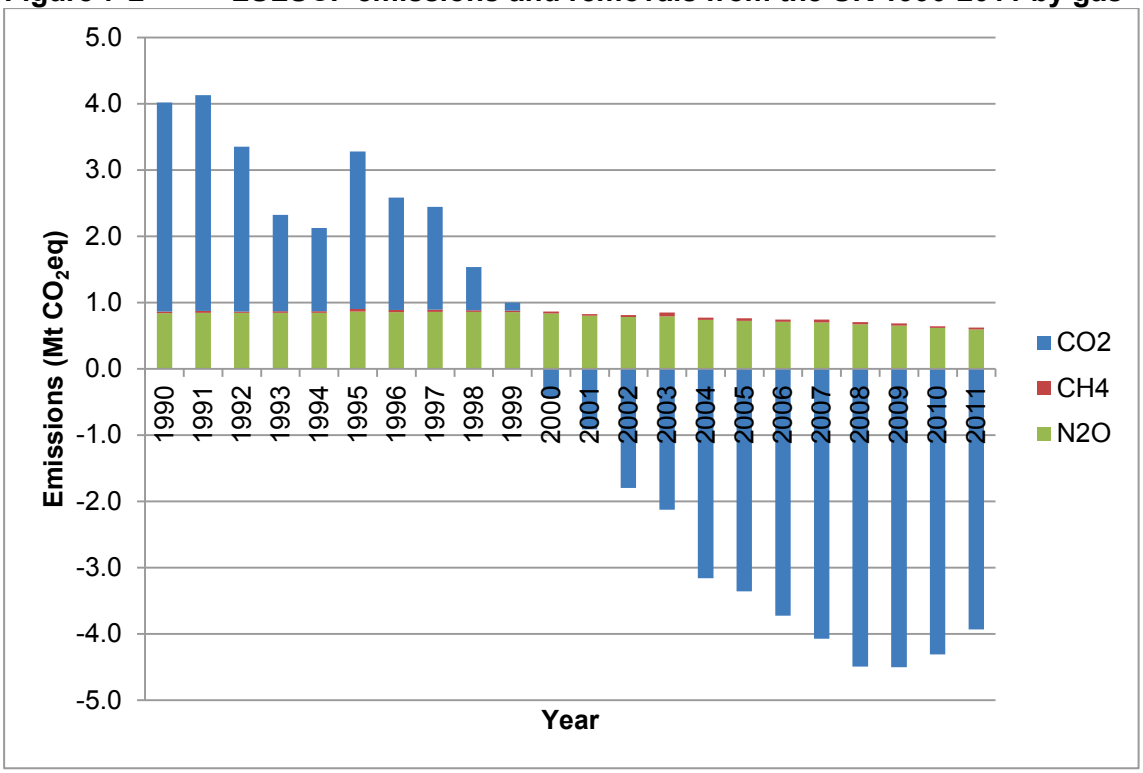


Figure 7-2 LULUCF emissions and removals from the UK 1990-2011 by gas



The inclusion of new activities and the revisions to activity data are described in this chapter and **Annex 3.7** on methods used to estimate emissions and removals. Activities under Article

3.3 and Article 3.4 of the Kyoto Protocol are reported in **Chapter 11**. Each section of this chapter will discuss carbon stock changes and then GHG emissions. Planned improvements to the inventory are described in the relevant category. Additional information on LULUCF and KP-LULUCF reporting will be made available at http://ecosystemghg.ceh.ac.uk/ which is undergoing redevelopment.

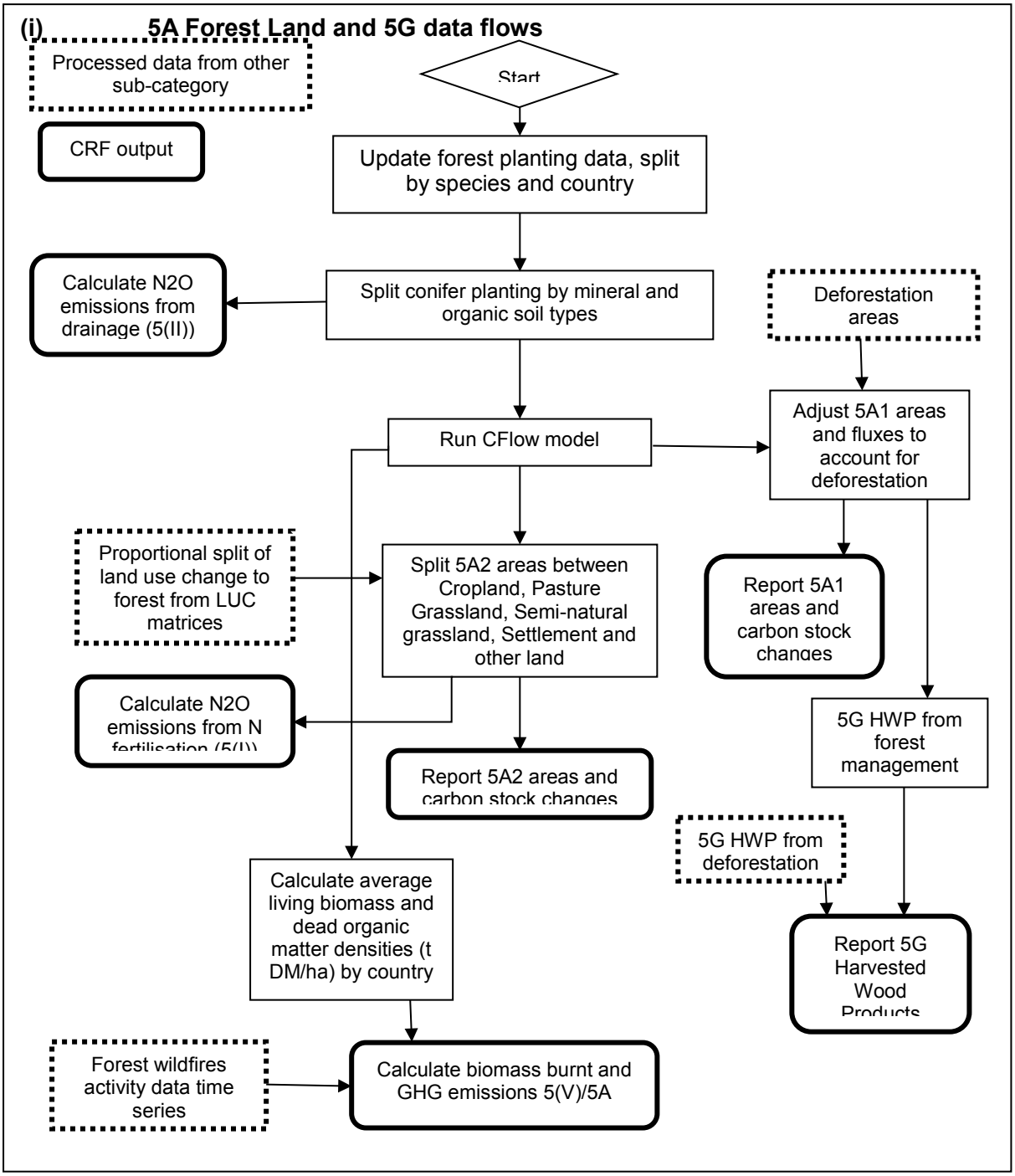
Greenhouse gas emissions and removals from the UK Crown Dependencies (CDs) and Overseas Territories (OTs) are reported under the relevant categories of CRF Sector 5. The data, assumptions and methodologies are explained in section 7.9. The availability of data for the different OTs and CDs is very variable, so that emission estimates can only be made for the Crown Dependencies of Jersey, Guernsey and the Isle of Man and the Overseas Territory of the Falkland Islands. These four comprise over 95% of the area in all the OTs and CDs. Gibraltar wished to produce its own inventory: in this case LULUCF net emissions/removals are likely to be extremely small, given the size of the country (6km^2), and will have little impact on overall numbers. A lack of suitable data for the Caribbean territories (as discussed in the 1990-2006 NIR) makes it impossible to create inventories for them at the present time (these territories were contacted in 2011 for the preparation of the 1990-2010 inventory but data is still insufficient for inventory compilation).

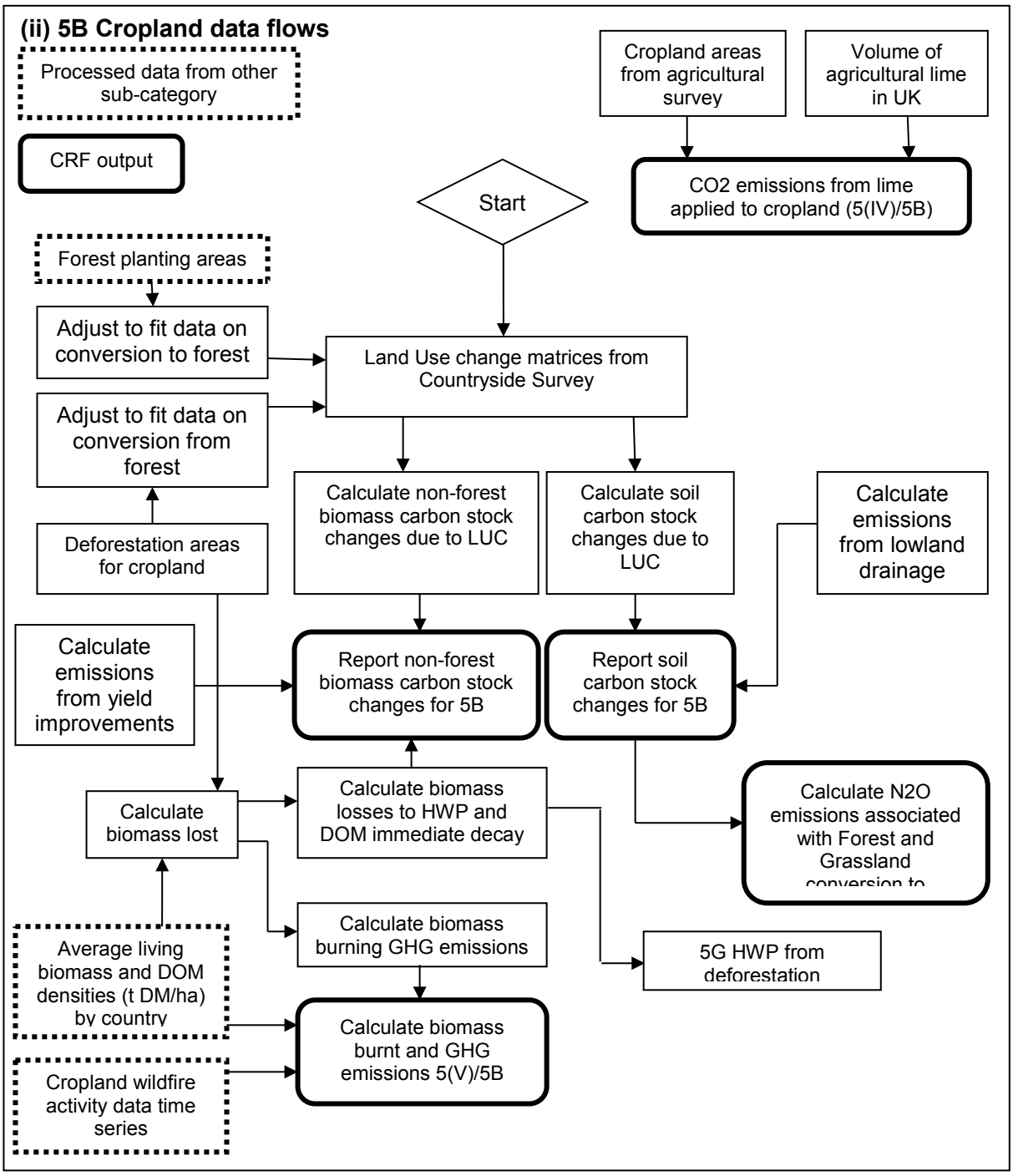
7.1.1 The land use transition matrix

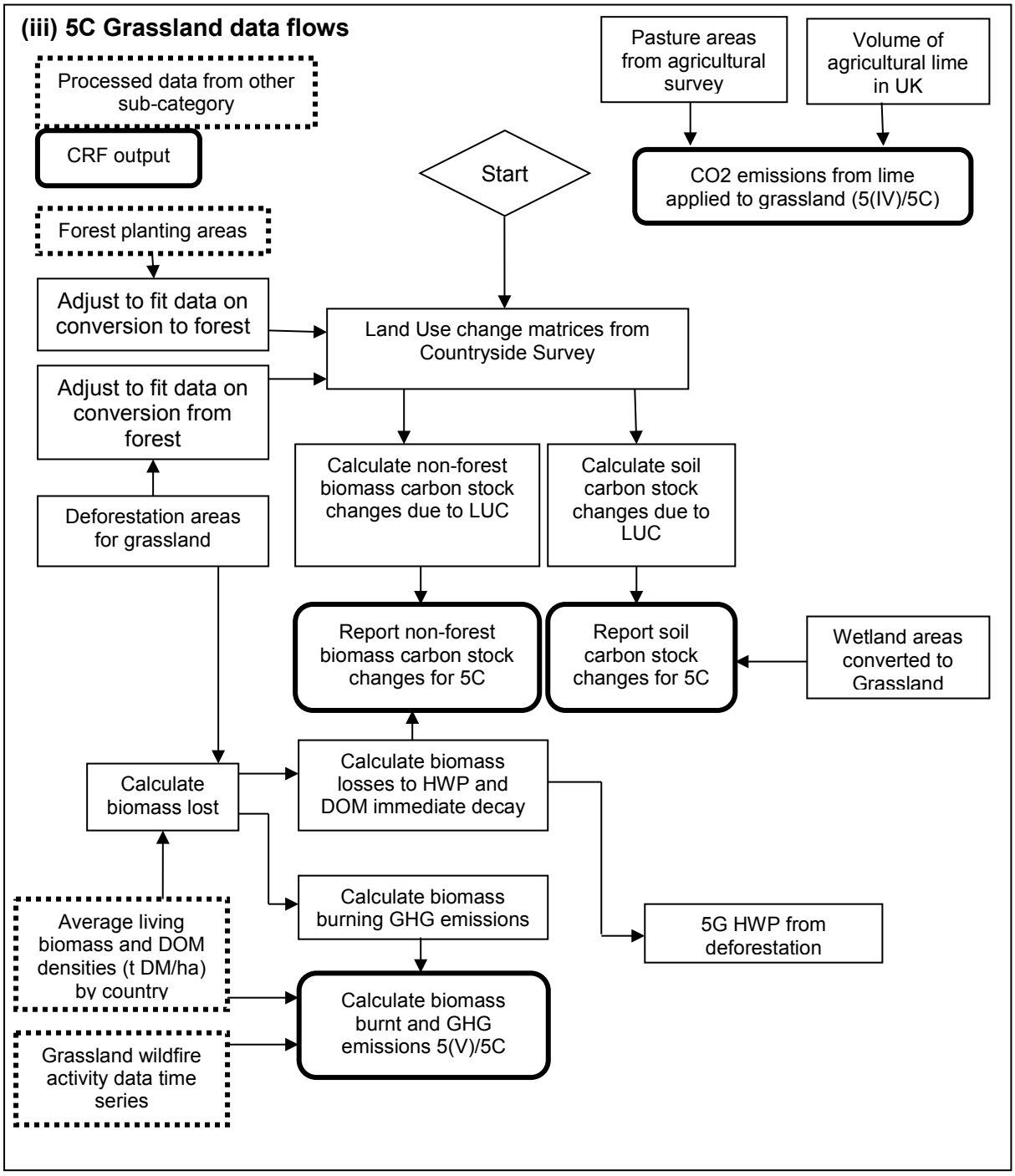
Reporting in CRF Sector 5 is based on broad land categories: Forest Land, Cropland, Grassland, Wetlands, Settlements and Other Land. According to the IPCC Good Practice Guidance for LULUCF, all land areas within a country should be assigned to one of these categories. UK definitions for the land use categories are given in the individual category sections in this chapter.

Areas of land use and land use change are compiled from various sources. Areas of forest land come from statistics published by the Forestry Commission. Areas of Cropland, Grassland and Settlements in 1990, 1998 and 2007 come from the Broad Habitat areas reported for each country (England, Scotland, Wales and Northern Ireland) in the Countryside Surveys (Countryside Survey 2009; Norton *et al*. 2009; Smart *et al*. 2009; Cooper *et al*. 2009). The area reported in the Wetlands category is the area undergoing active commercial peat extraction or that has only ceased extraction since 1990 (see **Section 7.5** for further information) and the area of inland water. Other Land includes the area of land not identified within the other categories. Areas of land use change to Forest (afforestation) come from planting data provided by the Forestry Commission, areas of land use change from Forest (deforestation) come from Forestry Commission data, the Department for Communities and Local Government and the Countryside Survey dataset. Other land use change data comes from the changes between the three Countryside Surveys (1990, 1998 and 2007), rolled forward to 2011. A decision tree has been developed to show the hierarchy between different data sources (**Figure 7-3**). Further information on how data are used to produce LULUCF calculations may be found in **Annex 3.7**.

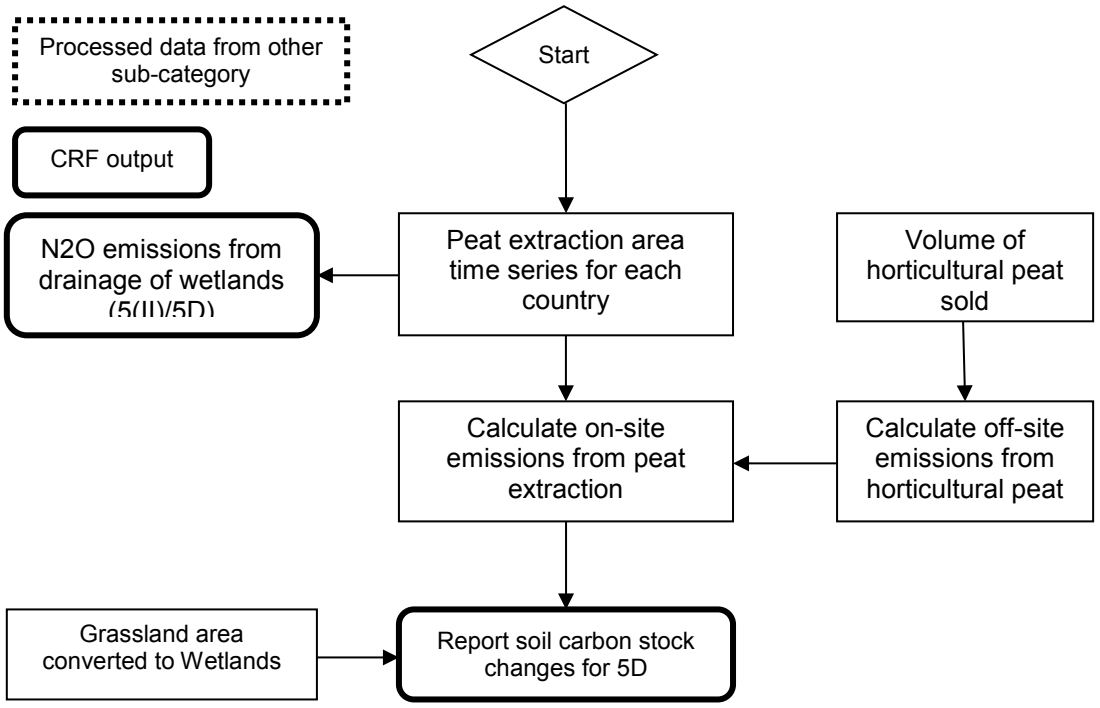
Figure 7-3 Data flow diagrams for each land use sub-category, showing cross-linkages between sectors: (i) 5A and 5G, (ii) 5B, (iii) 5C, (iv) 5D and (v) 5E



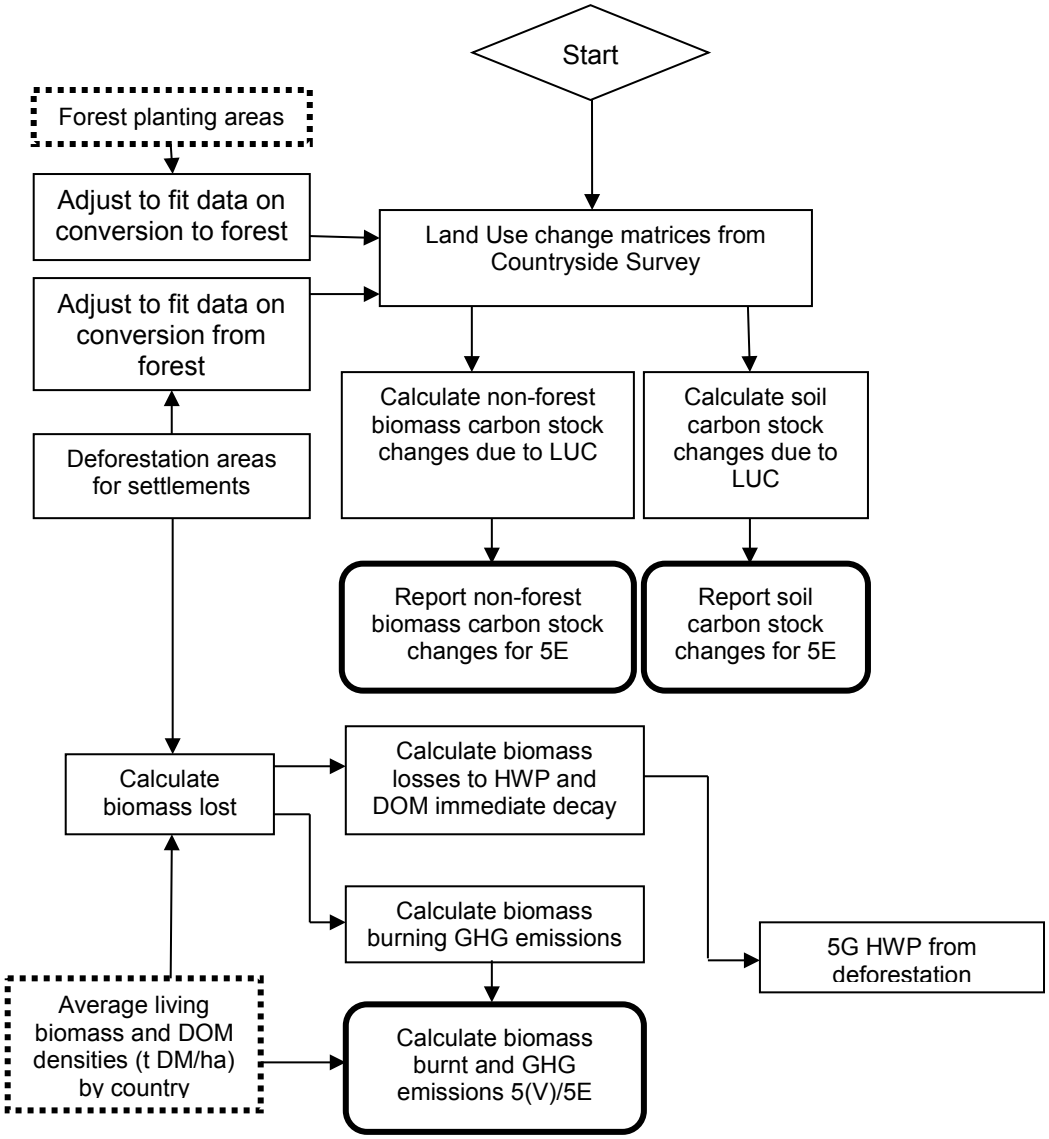

(ii) 5B Cropland data flows
Processed data from other sub-category
CRF output
Cropland areas from agricultural survey
Volume of agricultural lime in UK
CO2 emissions from lime applied to cropland (5(IV)/5B)
Start
Forest planting areas
Adjust to fit data on conversion to forest
Land Use change matrices from Countryside Survey
Adjust to fit data on conversion from forest
Calculate non-forest biomass carbon stock changes due to LUC
Calculate soil carbon stock changes due to LUC
Calculate emissions from lowland drainage
Deforestation areas for cropland
Calculate emissions from yield improvements
Report non-forest biomass carbon stock changes for 5B
Report soil carbon stock changes for 5B
Calculate biomass losses to HWP and DOM immediate decay
Calculate biomass lost
Calculate N2O emissions associated with Forest and Grassland
Calculate biomass burning GHG emissions
5G HWP from deforestation
Average living biomass and DOM densities (t DM/ha) by country
Calculate biomass burnt and GHG emissions 5(V)/5B
Cropland wildfire activity data time series


(iii) 5C Grassland data flows
Pasture areas from agricultural survey
Volume of agricultural lime in UK
Processed data from other sub-category
CRF output
Start
CO2 emissions from lime applied to grassland (5(IV)/5C)
Forest planting areas
Adjust to fit data on conversion to forest
Land Use change matrices from Countryside Survey
Adjust to fit data on conversion from forest
Calculate non-forest biomass carbon stock changes due to LUC
Calculate soil carbon stock changes due to LUC
Deforestation areas for grassland
Report non-forest biomass carbon stock changes for 5C
Report soil carbon stock changes for 5C
Wetland areas converted to Grassland
Calculate biomass lost
Calculate biomass losses to HWP and DOM immediate decay
Calculate biomass burning GHG emissions
5G HWP from deforestation
Average living biomass and DOM densities (t DM/ha) by country
Calculate biomass burnt and GHG emissions 5(V)/5C
Grassland wildfire activity data time series

(iv) 5D Wetlands data flows



(v) 5E Settlements data flows



The 2011 ERT recommended the inclusion of the full set of annual land use change matrices in the NIR (**Table 7-1**). The Standard Area Measurement to mean high water is used for the total area of the UK (24,415 kha) (Office for National Statistics 2011): there is some minor variation from this in the early years of the time series (>0.05%). The area of inland water (164.1 kha) is now explicitly reported in the Wetlands category.

Table 7-1 Annual land use change matrices 1990-2011

1990 To 1991

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2781	2	19	0	1	0	2802
Cropland	0	6022	96	0	1	0	6119
Grassland	0	83	13260	0	5	0	13348
Wetland	0	0	0	172	0	0	172
Settlement	1	2	13	0	1711	0	1728
Other Land	0	0	0	0	0	258	258
Total	2782	6110	13388	172	1718	259	24428

1991 To 1992

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2801	2	17	0	1	0	2821
Cropland	0	6031	96	0	1	0	6128
Grassland	0	83	13222	0	5	0	13310
Wetland	0	0	0	172	0	0	172
Settlement	1	2	13	0	1720	0	1737
Other Land	0	0	0	0	0	258	258
Total	2802	6119	13348	172	1727	258	24426

1992 To 1993

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2820	2	16	0	1	0	2838
Cropland	0	6040	96	0	1	0	6137
Grassland	0	83	13184	0	5	0	13273
Wetland	0	0	0	172	0	0	172
Settlement	1	2	13	0	1729	0	1746
Other Land	0	0	0	0	0	258	258
Total	2821	6128	13309	172	1736	258	24424

1993 To 1994

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2837	2	16	0	1	0	2856
Cropland	0	6049	96	0	1	0	6146
Grassland	0	83	13147	0	5	0	13236
Wetland	0	0	0	172	0	0	172
Settlement	1	2	13	0	1738	0	1755
Other Land	0	0	0	0	0	258	258
Total	2838	6137	13273	172	1745	258	24423

1994 To 1995

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2855	2	15	0	1	0	2874
Cropland	0	6058	96	0	1	0	6155
Grassland	0	83	13111	0	5	0	13200
Wetland	0	0	0	172	0	0	172
Settlement	1	2	13	0	1747	0	1764
Other Land	0	0	0	0	0	258	258
Total	2856	6146	13236	172	1754	258	24423

1995 To 1996

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2873	2	17	0	1	0	2893
Cropland	0	6067	96	0	1	0	6164
Grassland	0	83	13072	0	5	0	13161
Wetland	0	0	0	172	0	0	172
Settlement	1	2	13	0	1757	0	1773
Other Land	0	0	0	0	0	258	258
Total	2874	6155	13199	172	1763	258	24420

1996 To 1997

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2892	2	14	0	1	0	2908
Cropland	0	6076	96	0	1	0	6173
Grassland	0	83	13037	0	5	0	13126
Wetland	0	0	0	172	0	0	172
Settlement	1	2	13	0	1765	0	1782
Other Land	0	0	0	0	0	258	258
Total	2893	6164	13161	172	1772	258	24418

1997 To 1998

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2907	2	15	0	1	0	2924
Cropland	0	6085	96	0	1	0	6182
Grassland	0	83	13002	0	5	0	13091
Wetland	0	0	0	171	0	0	171
Settlement	1	2	13	0	1774	0	1791
Other Land	0	0	0	0	0	258	258
Total	2908	6173	13126	172	1781	258	24417

1998 To 1999

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2923	2	14	0	1	0	2940
Cropland	0	6094	96	0	1	0	6191
Grassland	0	83	12967	0	5	0	13056
Wetland	0	0	0	171	0	0	171
Settlement	1	2	13	0	1783	0	1800
Other Land	0	0	0	0	0	257	257
Total	2924	6182	13091	172	1790	258	24416

1999 To 2000

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2938	2	13	0	2	0	2955
Cropland	0	6103	96	0	1	0	6200
Grassland	0	83	12934	0	5	0	13023
Wetland	0	0	0	171	0	0	171
Settlement	1	2	13	0	1791	0	1808
Other Land	0	0	0	0	0	257	257
Total	2939	6191	13056	172	1799	258	24414

2000 To 2001

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2955	2	13	0	2	0	2972
Cropland	0	6093	52	0	0	0	6145
Grassland	1	99	12948	0	8	0	13056
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1799	0	1815
Other Land	0	0	0	0	0	257	257
Total	2956	6199	13024	171	1809	257	24416

2001 To 2002

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2970	2	14	0	2	0	2988
Cropland	0	6038	52	0	0	0	6090
Grassland	1	99	12980	0	8	0	13088
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1806	0	1822
Other Land	0	0	0	0	0	257	257
Total	2971	6144	13056	171	1816	257	24416

2002 To 2003

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2987	2	10	0	2	0	3001
Cropland	0	5984	52	0	0	0	6036
Grassland	1	99	13016	0	8	0	13124
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1813	0	1829
Other Land	0	0	0	0	0	256	256
Total	2989	6090	13089	171	1822	257	24417

2003 To 2004

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	2998	2	10	0	1	0	3011
Cropland	0	5930	52	0	0	0	5982
Grassland	1	99	13052	0	8	0	13160
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1820	0	1836
Other Land	0	0	0	0	0	256	256
Total	3000	6036	13124	171	1829	256	24416

2004 To 2005

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	3008	1	9	0	1	0	3020
Cropland	0	5876	52	0	0	0	5928
Grassland	1	99	13088	0	8	0	13196
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1827	0	1843
Other Land	0	0	0	0	0	256	256
Total	3010	5981	13159	171	1836	256	24414

2005 To 2006

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	3018	1	8	0	1	0	3029
Cropland	0	5822	52	0	0	0	5874
Grassland	1	99	13125	0	8	0	13233
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1835	0	1851
Other Land	0	0	0	0	0	256	256
Total	3020	5927	13195	171	1844	256	24414

2006 To 2007

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	3028	1	6	0	1	0	3036
Cropland	0	5769	52	0	0	0	5821
Grassland	1	99	13164	0	8	0	13272
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1843	0	1859
Other Land	0	0	0	0	0	256	256
Total	3029	5874	13233	171	1852	256	24415

2007 To 2008

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	3034	1	8	0	1	0	3044
Cropland	0	5716	52	0	0	0	5768
Grassland	1	99	13202	0	8	0	13310
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1850	0	1866
Other Land	0	0	0	0	0	255	255
Total	3035	5821	13272	171	1859	256	24414

2008 To 2009

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	3042	1	5	0	1	0	3049
Cropland	0	5663	52	0	0	0	5715
Grassland	1	99	13243	0	8	0	13351
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1858	0	1874
Other Land	0	0	0	0	0	255	255
Total	3044	5768	13311	171	1867	255	24415

2009 To 2010

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	3047	1	5	0	1	0	3053
Cropland	0	5610	52	0	0	0	5662
Grassland	1	99	13284	0	8	0	13392
Wetland	0	0	0	171	0	0	171
Settlement	1	5	10	0	1865	0	1881
Other Land	0	0	0	0	0	255	255
Total	3049	5715	13351	171	1874	255	24414

2010 To 2011

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	3051	1	4	0	1	0	3056
Cropland	0	5661	6	0	0	0	5666
Grassland	1	0	13365	0	0	0	13366
Wetland	0	0	0	171	0	0	171
Settlement	1	0	17	0	1881	0	1899
Other Land	0	0	0	0	0	255	255
Total	3052	5661	13392	171	1882	255	24413

2011 To 2012

From / To	Forest	Cropland	Grassland	Wetland	Settlement	Other Land	Total
Forest	3055	1	6	0	1	0	3063
Cropland	0	5666	6	0	0	0	5672
Grassland	1	0	13337	0	0	0	13338
Wetland	0	0	0	171	0	0	171
Settlement	1	0	17	0	1899	0	1916
Other Land	0	0	0	0	0	255	255
Total	3056	5667	13366	171	1900	255	24415

Work is being undertaken as part of the LULUCF improvement programme to improve the land use change matrix. This will develop a new approach to assimilate available land use datasets (ecological, agricultural and forestry land use datasets) into land use vectors. These vectors are able to represent the range of land use histories across a region over time (a statistical assessment of how much land of each type changed land use and when). Recent work has concentrated on the development of the data assimilation code. An approach has been developed that uses Bayesian Calibration by means of Markov Chain Monte Carlo (MCMC) to find the most plausible vectors generated from land use change matrices (derived from the CEH Countryside Survey (CS)) and their areas given the available land use data. The method has been developed to sample from the Dirichlet distribution which ensures that the total land use area is conserved. We are currently validating this Dirichlet based method on CS data where the answer in terms of areas of land-use vectors is known. After this validation step we will apply the method to larger regions and the focus of the work will shift more towards the other main task for this year, the collation of appropriate land use datasets.

The areas of land in the different land use categories in the Overseas Territories and Crown Dependencies are shown in **Table 7-2**. There is insufficient data to construct full land use change matrices.

Table 7-2 Areas of land by category in the Crown Dependencies and Overseas Territories 1990-2011, kha

Land category	Sub-category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Forest remaining Forest		2.4	2.5	2.6	2.8	2.9	3.0	3.1	3.3	3.4	3.5	3.7
Land converted to forest		2.1	2.0	1.9	1.7	1.6	1.5	1.3	1.2	1.1	0.9	0.8
Cropland remaining Cropland		12.0	11.9	11.8	11.8	11.5	11.0	11.0	10.7	11.0	10.5	10.0
Land converted to Cropland	Grassland converted to Cropland	0.1	0.1	0.1	0.2	0.2	0.1	0.5	0.8	0.9	0.9	1.0
Grassland remaining Grassland		1236.6	1236.6	1255.6	1247.4	1255.2	1257.2	1171.7	1168.5	1167.7	1168.1	1168.1
Land converted to Grassland	Cropland converted to Grassland	1.7	1.7	1.8	2.9	3.2	3.7	6.9	6.9	7.2	7.5	7.9
Land converted to Grassland	Settlement converted to Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Settlements remaining Settlements		9.7	9.8	9.8	9.7	10.0	10.0	10.0	10.1	10.2	10.2	10.3
Land converted to	Grassland converted to	1.0	1.0	0.9	1.0	1.0	0.9	0.9	0.9	1.0	1.0	1.0

Land category	Sub-category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Settlement	Settlements											
Other Land remaining Other Land		26.9	27.0	6.9	13.9	5.9	4.0	86.0	89.1	88.9	88.6	88.4
Land converted to Other Land		0.1	0.1	1.2	1.2	1.2	1.2	1.2	1.2	1.4	1.4	1.5
Total area		*1292.7*	*1292.7*	*1292.7*	*1292.7*	*1292.7*	*1292.7*	*1292.7*	*1292.7*	*1292.7*	*1292.7*	*1292.7*

Land category	Sub-category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Forest remaining Forest		3.8	3.8	3.9	4.0	4.1	4.2	4.2	4.3	4.4	4.5	4.5
Land converted to forest		0.8	0.7	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3	0.4
Cropland remaining Cropland		9.5	9.3	9.0	8.6	8.6	8.5	8.5	8.3	8.4	7.7	7.5
Land converted to Cropland	Grassland converted to Cropland	1.0	1.1	1.1	1.3	1.5	1.7	2.0	2.3	2.4	2.4	2.4
Grassland remaining		1168.0	1167.7	1156.8	1157.3	1155.3	1162.7	1160.6	1150.1	1148.5	1133.7	1166.8

Land category	Sub-category	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Grassland												
Land converted to Grassland	Cropland converted to Grassland	8.5	9.3	9.6	9.6	9.5	13.1	13.1	13.7	15.5	15.3	16.0
Land converted to Grassland	Settlement converted to Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1
Settlements remaining Settlements		10.3	10.3	10.3	10.4	10.4	10.4	10.4	11.0	11.1	11.1	11.2
Land converted to Settlement	Grassland converted to Settlements	1.0	1.1	1.1	1.2	1.2	1.3	1.3	1.5	1.5	1.5	1.5
Other Land remaining Other Land		87.8	87.5	97.9	97.5	99.0	87.4	89.3	95.5	95.1	110.6	76.9
Land converted to Other Land		1.9	1.9	2.1	2.3	2.6	3.0	3.0	5.6	5.6	5.6	5.6
Total area		*1292.7*	*1292.7*	*1292.7*	*1292.7*	*1292.8*	*1292.8*	*1292.8*	*1292.8*	*1292.8*	*1292.8*	*1292.9*

Total land areas for reported OTs and CDs: Isle of Man = 57.20 kha, Guernsey = 6.30 kha, Jersey = 11.87 kha, Falkland Islands = 1217.30 kha. The Caribbean Overseas Territories are not included in these areas: Bermuda = 5.4 kha, Cayman Islands = 26.4 kha, Montserrat = 10.2 kha

7.2 CATEGORY 5A – FOREST LAND

7.2.1 Description

Emissions sources	5A Forest Land: carbon stock change 5A Forest Land: 5(I) Direct N_2O emissions from N fertilisation of Forest Land 5A Forest Land:5(II) Non-CO_2 emissions from drainage of soils 5A Forest Land: 5(V) Biomass burning
Gases Reported	CO_2, CH_4, N_2O
Methods	T3 for carbon stock changes, T1 for other emissions
Emission Factors	Country-specific for T3 methods
Key Categories (Trends)	None identified
Key Categories (Level)	5A (CO_2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 3
Completeness	No known omissions
Major improvements since last submission	Inclusion of new activities (N_2O from forest drainage)

This category is divided into Category 5.A.1 Forest remaining Forest Land and Category 5.A.2 Land converted to Forest Land. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland. This category uses a 20-year transition period for land use conversion to Forest in the latest inventory.

Forest Land is the biggest land use sink in the UK and includes carbon stock gains and losses and GHG emissions from forest management. All UK forests are classified as temperate and about 68% of these have been planted since 1921 on land that had not been forested for many decades.

The UK reports carbon stock changes in all forests planted since 1921 (when the first national survey of forests was undertaken). Forest surveys have been intermittent in the UK and there is no network of permanent sample plots as exists. Consequentially, estimates of carbon stock gains and losses for biomass and soils are modelled based on planting history and yield classes. The area of forest established before 1921 is reported in 5.A.1 – these areas are assumed to be in long-term carbon balance so have no associated carbon stock changes. Work is in progress to re-examine this assumption. The forest area and carbon stock changes in 5.A.1 are adjusted to take account of losses of forest land converted to other categories. Land use change from Cropland, Grassland and Settlements are considered and carbon stock changes on mineral and organic soils are reported separately.

In the UK nitrogen fertilizers are only applied to forests when it is absolutely necessary. This would occur during the first rotation on 'poor' soils, such as reclaimed slag heaps, impoverished brown field sites and upland organic soils. In terms of the inventory, this means that N fertilization is assumed for areas of Settlements converted to Forest Land and Grassland converted to Forest Land on organic soils. N_2O emissions from this fertilization are reported under 5.A.2 in Table 5(I). Nitrogen fertilizers are not generally applied to native

woodlands, mature forests or re-planted forests in the UK, so emissions of N_2O from N fertilization of forests (Table 5(I)) for 5.A.1 are reported as Not Occurring.

Emissions of non-CO_2 emissions from forest drainage (Table 5(II)) are reported for the first time in this inventory. This also led to a re-assessment of the areas of forest planting on mineral and organic soils, affecting soil carbon stock changes. A detailed description of the new methodology and activity data is given in Annex 3.7.

Controlled burning of forest land (for example for habitat management) does not take place in the UK. Wildfires do occur but the activity data is not sufficient to split between 5.A.1 and 5.A.2. Therefore emissions of greenhouse gases from wildfires are all reported under 5.A.1 in Table 5(V). It is assumed that land use change does not occur following wildfire.

The data reported for the UK in Sectoral Table 5 in the Information item "Forest Land converted to other Land-Use Categories" includes both changes in carbon stock in biomass and soils under "Net CO_2 emissions/removals".

7.2.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The UK uses Approach 2 (IPCC 2006) for the representation of land use areas in the inventory, and compiles several different data sources into a non-spatially-explicit land use conversion matrix. The data sources are available at the individual country level (England, Scotland, Wales and Northern Ireland) and results are combined to give UK totals.

The agencies responsible for forests in the UK are the Forestry Commission (England, Scotland and Wales) and the Forest Service (Northern Ireland). The areas of forest planted annually are published in Forest Statistics (described below) and the Forestry Commission also provides a more detailed breakdown of the published numbers to the LULUCF sector compilers. The allocation of land use change from other land use categories is based on the proportional changes in the land use change matrices from the Countryside Survey. This allocation has been updated to incorporate the latest information from the 2007 Countryside Survey.

Forestry Statistics is published each September by the Forestry Commission at http://www.forestry.gov.uk/statistics. It includes national statistics on new planting and restocking, based on operational data for the Forestry Commission/Forest Service estates, grant scheme data and estimates of planting without grant aid. There are annual statistics on woodland area in each country. From 2010, these are obtained from the National Forest Inventory, adjusted for new planting; at present no adjustment is made for woodland converted to another land use. For earlier years, figures are based on the 1995-99 National Inventory of Woodland and Trees. The sources and methodologies are described in more detail in the Sources section of the publication.

The National Inventory of Woodland and Trees (NIWT) 1995-99 http://www.forestry.gov.uk/inventory provided woodland statistics for Great Britain, countries (England, Wales and Scotland) and regions/counties. The Main Woodland Survey for woods over 2 hectares determined total woodland area using a digital woodland map, and collected field survey data for a sample of around 1% of area using one-hectare sample squares; it was supplemented by a Survey of Small Woodland & Trees. No similar woodland inventory exists for Northern Ireland.

The new National Forest Inventory (NFI) for Great Britain (http://www.forestry.gov.uk/inventory) comprises a digital woodland map based on

comprehensive aerial photography and a field survey using one-hectare sample squares. The digital map and field survey now cover all woodland areas down to 0.5 hectares, while the core field survey sample has been reduced to around 0.5% of area. An initial digital woodland map was published in spring 2011. The field survey started in 2010 and should be completed in 2014. Interim results will be used for the softwood production forecast in 2012.

7.2.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

The definition of woodland in United Kingdom forestry statistics and used for the greenhouse gas inventory is land under stands of trees with a canopy cover of at least 20% (or having the potential to achieve this), including integral open space, and including felled areas that are awaiting restocking. There is no minimum size for a woodland. The 1995-99 National Inventory of Woodland and Trees mapped all areas down to 2.0 hectares, but information from the survey of small woods and trees was used to calculate areas down to 0.1 hectares, and this was used as the basis for the annual updates in Forestry Statistics up to 2010.

The definition of woodland has changed slightly between the NIWT and the NFI. The NFI (Forestry Commission 2011) uses a minimum area of 0.5 hectares (rather than 0.1 ha) and a lower integral open space threshold of 0.5 ha (as opposed to 1 ha), which requires a negative adjustment to areas. However, the main differences in 2010 GB woodland cover between the NFI (2982 kha) and previous estimates (2757 kha, Forestry Statistics 2010) arise from identified errors in the previous woodland survey, particularly the under-estimate of woodland areas between 0.5 and 2 hectares. Estimates of woodland loss are still being assessed, which will affect the total woodland area. The NFI area estimates are not used for this inventory submission, but will be used for the next submission once woodland loss estimates are confirmed.

The international definition of forest, as used for the Global Forest Resources Assessment and for State of Europe's Forests, is based on 10% canopy cover, a minimum height at maturity of 5m and minimum area of 0.5 hectares. This is estimated to give similar areas to the current UK woodland statistics, as the UK woodland in areas of 0.1-0.5 hectares balances the unrecorded area with 10-20% canopy cover. The UK report for the Global Forest Resources Assessment 2010 estimated that the area of woodland with 10-20% canopy cover is less than 50 thousand hectares.

For the Countryside Survey 2007 http://www.countrysidesurvey.org.uk/ field survey, woodland areas are required to have 25% canopy cover at the survey date. According to this definition, the CS woodland area should exclude areas that are awaiting restocking after harvest, and also areas of young trees (for 10 years or more) after new planting and restocking. The reported definition differed in previous Countryside Surveys, and there is some doubt whether the latest time series is fully consistent. Following Countryside Survey 2000, there was a study comparing the Countryside Survey results (field survey and Land Cover map) with NIWT 1995-99 and other woodland area statistics. Although the total woodland area in NIWT was similar to the two CS sources, the analysis found that the spatial overlap with each was only around 70%. The report included various explanations for differences, but was not able to give a full reconciliation (Howard *et al*. 2003). The area of woodland used in LULUCF reporting is taken from the statistics published by the Forestry Commission (see also Figure 7.4).

7.2.4 Methodological Issues

The carbon uptake by UK forests is calculated by a carbon accounting model, C-Flow, as the net change in the pools of carbon in standing trees, litter, soil and products from harvested material for conifer and broadleaf forests. The method can be described as Tier 3, as defined in the Good Practice Guidance for LULUCF (IPCC 2003). The model calculates the masses of carbon in the pools of new even-aged plantations that were clear-felled and then replanted at the time of Maximum Area Increment. Work is in progress to incorporate more detailed forest management into the inventory (see **Section 7.2.8**). The C-Flow model produces separate gains and losses for Carbon stock change in living biomass, rather than net change. A detailed description of the method used can be found in **Annex 3.7** for biomass, dead organic matter and soil.

Other greenhouse gas emissions, including forest fertilisation, wildfires and new estimates of N2O emissions from forest drainage, are estimated using Tier 1 or Tier 2 approaches, and are described in Annex 3.7.

In the 2007 ARR the ERT asked the UK to provide evidence to support the assumption of carbon balance in forest established before 1921. Simulations of UK forest conditions using the C-Flow and Forest Research CARBINE carbon accounting models have shown that, in the longer term, carbon stocks neither increase nor decrease. Rather, stocks fluctuate around a long term average value (Dewar, 1990, 1991; Dewar and Cannell, 1992; Thompson and Matthews, 1989). Typically in the UK, the long-term average stock is approached in <100 years after the time of woodland creation. This outcome is observed whether woodlands are left to grow undisturbed to achieve 'old growth' conditions or managed for production (Forest Research, recent unpublished model results). The assumption that woodlands in existence before 1921 collectively do not exhibit significant long-term changes in biomass stock in reporting periods relevant to the current inventory is consistent with these long-standing results. Further work is being undertaken in this area (see Section 7.2.8)

7.2.5 Uncertainties and Time-Series Consistency

An uncertainty analysis was undertaken in 2011 to reassess sources of uncertainty (input data, model parameters and structural/model choice) in the LULUCF sector and identify priority areas for improvement (**Annex 3.7.13**). Monte Carlo simulations were run to propagate input and parameter uncertainty for different source categories, and the uncertainty arising from model choice was quantified by using alternative sub-models for key processes. 5A Forest Land was estimated to have an uncertainty of 22% for net emissions in 1990 and 2009 (assumed to continue up to 2011) (slightly lower than the previous assessment of 25%). The main sources of uncertainty (ranked by standard deviation in output distributions) are afforestation model parameters, afforestation input data, forest soil carbon model choice and afforestation model choice.

The planting statistics used as activity data mostly come from operational systems, for grants and FC planting, and have no measures of statistical uncertainty attached to them. The grant-aided planting is allocated by date of payment, so all the recorded planting should have taken place. The new National Forest Inventory (NFI) field survey will provide better information on the reliability of the planting statistics, but the results from this are not yet available.

The wildfire activity data are estimated to have an uncertainty of 50% for 1990-2004 and 2010-2011 and 100% for 2005-2009, as these have been extrapolated. The IPCC default of 70% uncertainty is used for the emission factors.

In terms of time series consistency:

- For forest carbon stock changes, N fertilization of forests and non-CO_2 emissions from drainage, time series consistency is good as activity data are obtained consistently from the same national forestry sources.
- For emissions from wildfires, data have been collated from several published sources but all originate from the state forestry agencies so there is good time series consistency for 1990-2004. Data have been extrapolated for 2005-2009. A new and more complete data source has become available for 2010 onwards, but this is consistent with the previous data sources.

7.2.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10**. Information on forest planting and the area affected by wildfires is consistent with that reported to the FAO (2005, 2010).

As part of a separate research project, a comparison has been made of the predictions made by the CEH C-Flow model and Forest Research CARBINE model. The results demonstrated that the models produce consistent predictions when given the same input data and assumptions (e.g. about woodland management practices).

The first NFI output was a new map, released in spring 2011, which has been used to produce estimates of total woodland area. The NFI woodland field survey will provide direct assessment of woodland growing stock including species composition, stand structure, tree age (distribution) productivity indices, numbers of trees, and diameter and height distribution. Standing biomass (and carbon) in trees will be derived from these assessments using GB-specific conversion factors and allometric equations. A complete 5-year cycle of ground survey should be completed in 2014, at which point direct verification of tree forest carbon stocks should be possible. The ground survey also includes more qualitative assessments of deadwood biomass which should be sufficient to enable checks on reported estimates. The possibility for the ground survey to also include some form of soil assessments is under consideration but, at the present time, this is not planned as part of the NFI scope. The full National Forest Inventory results are expected to be published in 2015.

A review of inventory data and models has been undertaken (Levy and Rowland, 2011), during which data was collated and critically assessed on soil carbon stocks following afforestation. Generally, soil carbon stocks are assumed to increase after afforestation in the UK, following on as a result of the increased above-ground biomass. C-FLOW predicts that afforestation in the UK since 1920 has produced a carbon sink in the soil equivalent to one third of that sequestered in the above-ground biomass. In fact, in the UK studies which attempt to measure this, soil carbon stocks in forested plots were 15 to 60 % lower than in adjacent unplanted, grassland or moorland (Reay *et al.*, 2001; Chapman *et al*. 2003; Zerva and Mencuccini, 2005; Mitchell *et al*. 2007; Bellamy and Rivas-Casado, 2009; Levy and Clark, 2009). These results are in agreement with global meta-analyses, which have reported mean changes in soil carbon stocks of around -10 %, -7 %, +3 % and -4 % associated with conversion of pasture to forest plantation (Guo and Gifford, 2002; Berthrong *et al.*, 2009; Laganiere *et al.*, 2010; Poeplau *et al.*, 2011, respectively). The treatment of the litter layer in these studies is a significant uncertainty, as it is possible that some of the reported decreases in soil carbon following afforestation were compensated by increases in the above-ground litter layer, but these may not be included in the soil samples.

Work is planned to re-examine the suitability of the current soil carbon sub-model in C-Flow, in association with the move towards using the CARBINE model.

7.2.7 Category-Specific Recalculations

The overall net GHG sink in category 5A has fallen by 1-5% from the 2010 inventory (**Figure 7-4**). This is due to new activity data, and therefore emissions sources, for forest drainage (affecting CO_2 and N_2O) and wildfires (CO_2, CH_4 and N_2O). Details of and justifications for recalculations to data are given in **Table 7-3**.

Figure 7-4 5A Forest Land changes in net emissions between 2012 and 2013 submissions

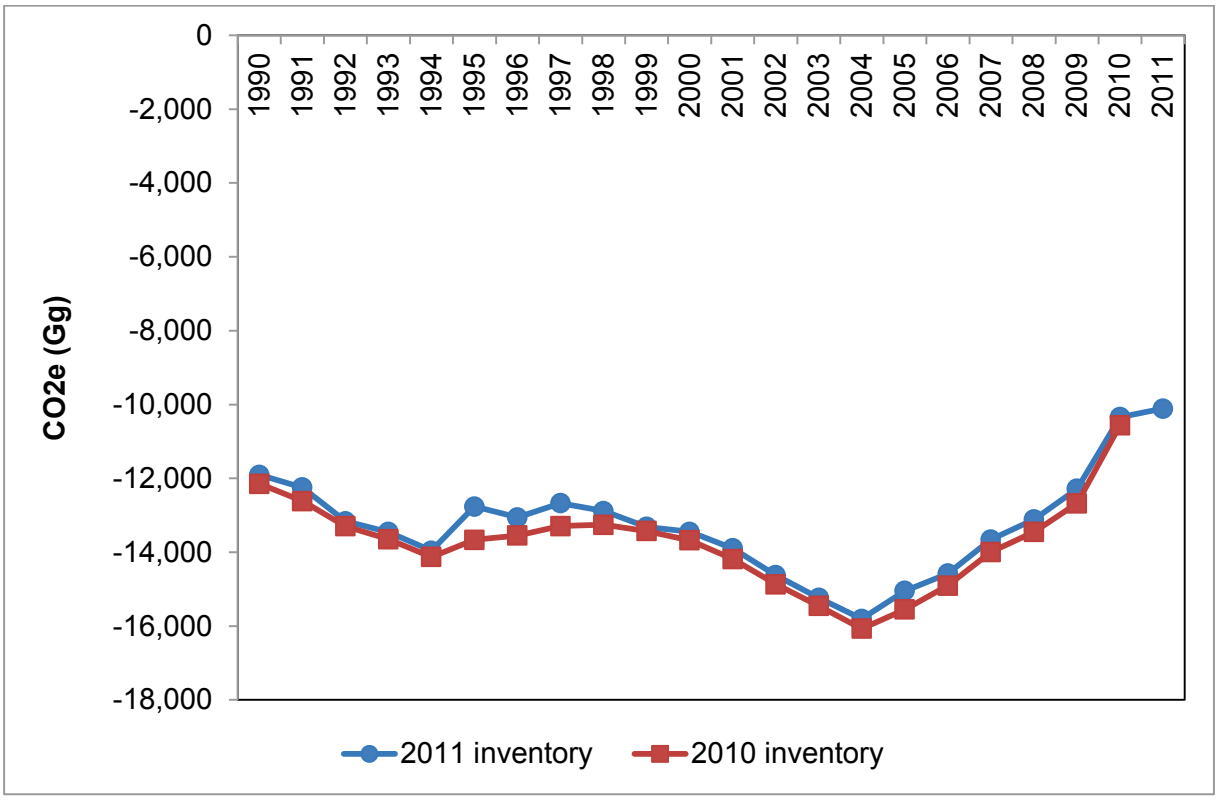


Table 7-3 5A Category specific recalculations to data since previous submission

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
5A1	Net Carbon stock change in mineral soils	508.03	634.78	501.08	640.56	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
5A1	Net Carbon stock change in organic soils	64.29	134.93	69.95	127.63	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
5A1/5(II)	Non-CO_2 emissions from drainage	NE	NE	0.16	0.18	Gg N_2O	New activity data for drainage on forest soils
5A1/5(V)	Biomass burning/Wildfires	46.91	89.20	227.35	245.43	Gg CO_2	Revised activity data on wildfires and inclusion of DOM in biomass burning
5A1/5(V)	Biomass burning/Wildfires	0.20	0.39	0.20	0.23	Gg CH_4	Revised activity data on wildfires and inclusion of DOM in biomass burning
5A1/5(V)	Biomass burning/Wildfires	0.00	0.00	0.01	0.01	Gg N_2O	Revised activity data on wildfires and inclusion of DOM in biomass burning
5A2	Carbon stock change in living biomass/Gains	3402.18	1686.63	3402.18	1686.71	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
5A2	Carbon stock change in living biomass/Losses	-1724.83	-931.69	-1724.83	-931.69	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
5A2	Net carbon stock change in dead organic matter	74.06	28.00	74.06	28.02	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
5A2	Net Carbon stock change in mineral soils	-97.78	51.61	-109.47	51.43	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
5A2	Net Carbon stock change in organic soils	-54.16	13.00	-43.82	13.11	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
5A2/5(I)	Direct N_2O emissions from N fertilisation	0.02	0.00	0.02	0.00	Gg N_2O	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage

7.2.8 Category-Specific Planned Improvements

The area reported under 5.A.1 Forest remaining Forest is likely to be revised when the final statistics on woodland loss become available from the new National Forest Inventory. National forest statistics do not currently capture forest conversion to other land uses, so a separate adjustment is made to the forest areas and carbon stock changes reported in the inventory. Although initial results from the National Forest Inventory became available in spring 2011, further work is being undertaken to resolve areas of woodland loss in the different countries of the UK to the required scale for reporting.

Forest Research has been carrying out an analysis of Forestry Commission GB National Inventory of Woodland and Trees (NIWT) data, for a base year of 2005, as well as records maintained in the Forestry Commission Sub-compartment Database (SCDB), for a base year of 2009, to estimate the detailed composition of woodlands in England, Scotland and Wales in terms of tree species, growth rates and types of management. The SCDB (which covers around one quarter of the forest area in Britain) gives detailed, stand-by-stand information about species, growth rate and management prescription. This is being combined with NFI data on the species composition of private woodlands to obtain an overall analysis of the status and management of woodlands in England, Scotland and Wales. Contact has also been made with experts in the Northern Ireland Forest Service with the aim of undertaking a similar exercise for Northern Ireland. At the same time, the Forest Research CARBINE forest carbon accounting model has been significantly upgraded to enable the representation of a much more complete range of tree species and growth rates, as well as many more examples of management prescriptions involving different rotation periods, no thinning, thinning and, where appropriate, management according to 'continuous cover' principles and even 'no management'. The methodology was successfully applied to Wales in 2012 and is now being rolled out to England and Scotland. Better estimates will be available following completion of the current NFI round in 2014.

Forest Research has been seeking to determine a better understanding of the contribution to the carbon balance made by woodlands established before 1921. This has involved analysing the Forestry Commission NIWT data for the base year of 2005 in combination with Forestry Commission reports on areas of new planting since 1920. This also involves complex modelling of changes in the age class structure of forest areas, based on species composition, growth rate and management of woodland areas, in particular rotation periods. The aim is to 'factor out' post-1920 woodlands from NFI data to obtain a picture of the age class structure, status and management of pre-1921 woodlands. An initial attempt to demonstrate proof of concept through development and application of an appropriate methodology to woodlands in Wales has been successful. The methodology is now being implemented in detail and applied to analysis of woodlands in England, Scotland and Wales. Contact has also been made with experts in the Northern Ireland Forest Service with the aim of undertaking a similar exercise for Northern Ireland.

Improved representation of the fate of forest carbon following harvesting is being achieved by taking more detailed account of woodland composition and management, in particular patterns of thinning and clear felling (on appropriate rotations) as part of the analysis being carried out by Forest Research as described earlier.

7.3 CATEGORY 5B – CROPLAND

7.3.1 Description

Emissions sources	5B Cropland: carbon stock change 5B Cropland:5(III) N_2O emissions from disturbance associated with LUC to Cropland 5B Cropland:5(IV) CO_2 emissions from agricultural lime application 5B Cropland:5(V) Biomass burning
Gases Reported	CO_2, CH_4, N_2O
Methods	T3 for carbon stock changes, T1 for other emissions
Emission Factors	Country-specific for T3 methods
Key Categories (Trends)	None identified
Key Categories (Level)	5B (CO_2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	Inclusion of new activity (biomass burning emissions from non-forest wildfires)

The category is disaggregated into 5.B.1 Cropland remaining Cropland and 5.B.2 Land converted to Cropland. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland.

Carbon stock changes in soils arising from historical land use change to Cropland more than 20 years before the inventory reporting year are reported under 5.B.1, along with (i) biomass carbon stock changes from yield improvements and (ii) organic soil carbon emissions from fenland drainage. Carbon stock change from (i) is the annual increase in the biomass of cropland vegetation in the UK that is due to yield improvements (from improved species strains or management, rather than fertilization or nitrogen deposition). Carbon stock changes from (ii) arise because fenland areas of England were drained many decades ago for agriculture (although there was no land use change). The soils in these areas are still emitting CO_2, i.e. there is an ongoing change in soil carbon stock.

Carbon stock changes and biomass burning emissions due to conversion of other land categories to Cropland in the previous 20 years before the reporting year are reported under category 5.B.2 (biomass burning emissions occur in the same year as the land use conversion). All forms of land use change, including deforestation, are considered and both mineral and organic soils are included. In some categories, e.g. Forest Land converted to Cropland, the area of land undergoing transition drops away to zero and is subsequently reported as Not Occurring.

Nitrous oxide emissions from disturbance associated with land-use conversion to cropland (Table 5(III)) are reported: these arise from Forest Land and Grassland being converted to Cropland.

Emissions of carbon dioxide from the application of limestone, chalk and dolomite to cropland are reported in Table 5(IV). The amount of agricultural lime applied relates to all areas of Cropland, therefore it will include areas in 5B1 and 5B2.

Emissions of CO_2, CH_4 and N_2O from biomass burning arising from forest land conversion to cropland are reported in Table 5(V). Burning of agricultural residues (cereal straw or stubble) are reported under category 4F Field Burning of Agricultural Residues. Emissions from wildfires on cropland are reported for the first time in this inventory: cropland wildfires are infrequent and emissions are small. Full details of the method and activity data are given in Annex 3.7.

7.3.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The UK uses Approach 2 (IPCC 2006) for the representation of land use areas in the inventory, and compiles several different data sources into a non-spatially-explicit land use conversion matrix. The data sources are available at the individual country level (England, Scotland, Wales and Northern Ireland) and results are combined to give UK totals.

Data sources that contain area information for reporting carbon stock changes and/or emissions from Cropland are habitat/landscape surveys, published statistics on agricultural lime and land use and an assessment of fenland drainage in England.

Decadal matrices of land use change from 1950 have been developed from the Monitoring Landscape Change project dataset (using a sample survey of aerial photographs in 1947 and 1980) (MLC 1986) and the ITE/CEH Countryside Surveys of 1984, 1990, 1998 and 2007 (Barr *et al*. 1993; Haines-Young *et al*. 2000; Cooper and McCann 2002; Carey *et al*. 2008), which are based on repeated sample field surveys. Case studies of land use matrix development for Scotland and Wales are described in the ECOSSE report (Smith *et al*. 2007), and the same approach has been used to develop matrices for England. Data for Northern Ireland before 1990 is limited but matrices have been developed using agricultural census and forestry data (Cruickshank and Tomlinson 2000): a combination of IPCC Approaches 1 and 2.

The areas of Cropland receiving lime are estimated from the cropland (tillage + bare fallow) area[37] reported in the annual June Agricultural Census and the proportions of arable areas receiving lime reported in the British Survey of Fertiliser Practice (2011).

Areas of lowland wetlands that are emitting carbon due to historical drainage (reported under Cropland remaining Cropland) have been assessed by Bradley (1997) and only occur in England.

[37] This does not include uncropped arable land such as set-aside or land managed in Good Agricultural and Environmental Condition (GAEC12).

7.3.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Cropland is defined in accordance with the Good Practice Guidance (IPCC 2003). For pre-1980 land use matrices cropland is the sum of the Crops and Market Garden land cover types in the Monitoring Landscape Change project (MLC 1986). Orchards should also have been included but were assigned to the Forestland category instead: this will be rectified, but is estimated to have a minor impact given the area of orchards in comparison to either the Cropland or Forestland categories. Post-1980, cropland is the sum of the Arable and Horticulture Broad Habitat types in the Countryside Survey. These have now been re-assigned to a single Broad Habitat class "Arable and horticulture" (Haines-Young *et al*. 2000, Appendix A), defined as:

"All arable crops such as different types of cereal and vegetable crops, together with orchards and more specialist operations such as market gardening and commercial flower growing. Freshly ploughed land, fallow areas, short-term set-aside and annual grass leys[1] are also included in this category."

7.3.4 Methodological Issues

Changes in biomass and soil carbon due to land use change are estimated using a land use matrix approach. The construction of the land use change matrices is described in **Annex 3.7**. The matrix approach has been updated to use a bottom-up approach (based on 20x20km squares), rather than a top-down approach based on national matrices. A dynamic model of carbon stock change is used with the land use change matrices to estimate soil carbon stock changes due to land use change. This uses a database of soil carbon density for the UK (Milne and Brown 1997; Cruickshank *et al*. 1998; Bradley *et al*. 2005) which has been constructed based on information on soil type, land cover and carbon content of soil cores. These densities included carbon to a depth of 1 m or to bedrock, whichever was the shallower, for mineral and peaty/mineral soils. Deep peat in the North of Scotland was identified separately and depths to 5 m are included.

In the dynamic model of soil carbon stock change, the change in equilibrium soil carbon density from the initial to the final land use during a transition is required. These are calculated for each land use category as averages for Scotland, England, Northern Ireland and Wales. The rate of loss or gain of soil carbon is dependent on the type of land use transition. A Monte Carlo approach is used to vary the rate of change, the area activity data and the values for soil carbon equilibrium (under initial and final land use) for all countries in the UK. The mean soil carbon flux for each region resulting from these imposed random choices was then reported as the estimate for the Inventory. Fluxes arising from land use change in the 20 years before the inventory year are reported under 5B2 Land converted to Cropland. Fluxes from historical land use change (more than 20 years before the inventory year) are reported under 5B1 Cropland remaining Cropland. A detailed description of the method is found in **Annex 3.7**. The calculations for each country are adjusted to remove increases in soil carbon due to afforestation, as the C-Flow model is used to estimate these fluxes.

N_2O emissions associated with the conversion of land to Cropland are reported using the areas of forest land and grassland converted to cropland from the land use change matrices and the IPCC Tier 1 emission factors.

7.3.5 Uncertainties and Time-Series Consistency

The Approach 1 (error propagation) uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5B Cropland was estimated to have an uncertainty of 52% for net emissions in 1990 and 2009 (assumed to continue up to 2011) (slightly higher than the previous assessment of 50%).

Recent work on quantifying uncertainties in the inventory has focussed on forest modelling (see **Chapter 11**, **Section 3.1.5**). The uncertainty analysis (see **Annex 3.7.13**) has been extended to encompass the whole of the existing inventory methodology, applying uncertainty quantification more widely and rigorously to all model parameters and empirical conversion factors, and to quantify the impact of those uncertainties on the inventory.

The areas undergoing land use change are the biggest source of uncertainty in the LULUCF inventory, but model choice and soil carbon parameters are also significant. Work on assimilating more land use data sets is planned for 2012-2014, which should constrain the high uncertainties associated with areas of land use change.

For liming, uncertainty in both the activity data and emission factor are judged to be low. The main source of uncertainty in the estimates is caused by non-publication of some data due to commercial restrictions although these are not judged to be very significant.

Fenland drainage has the largest uncertainties of the minor emissions sources (i.e. not land use change or afforestation) as the effects of drainage are highly uncertain (as is the reversal of such drainage).

The wildfire activity data are estimated to have an uncertainty of 50% for 2010-2011 and 100% for 1990-2009, as these years have been extrapolated. The IPCC default of 70% uncertainty is used for the emission factors.

In terms of time series consistency:

- For biomass increases due to yield improvements (5B1) activity data are reported as a constant annual average value.
- For fenland drainage (5B1) the activity data for the model come from a single source which provides good time series consistency.
- For liming (5B) there is good time series consistency as there has been continuity in the published data sources.
- For changes in non-forest biomass and soil carbon stocks due to land use change the data sources for Great Britain have separate good internal consistency. Consistency between these and Northern Ireland data sources has improved with better methodological integration between land use surveys.
- For emissions due to biomass burning after conversion of Forest Land to Cropland, the time series consistency has improved to high with the introduction of country-specific data sets.
- For emissions from wildfires, a new activity dataset became available for 2010 onwards. Burnt areas have been extrapolated back to 2005 based on remote sensing data, but between 1990 and 2005 there is no appropriate data to use for extrapolation.

7.3.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10**.

A resampling of the 1980-based National Soil Inventory (NSI) in England and Wales in 1995-2003 found large losses of soil carbon across all land use types (Bellamy *et al*. 2005). As part of the supporting research for the LULUCF inventory project, Bellamy and Rivas-Casado (2009) attempted to identify NSI sites where there was sufficient land management information to determine the relationship between changes in soil carbon and differences in land management. Unfortunately, there were insufficient co-incident data (for example, none of 1314 Countryside Survey sample sites were closer than 1.9 km to a resampled NSI site) to allow these relationships to be investigated except at Forest Land sites (see **section 7.2.6**). Further work by Kirk and Bellamy (2010) has concluded that the losses measured between 1980 and 1995 -2003 were mainly due to land use/land management changes before 1980 – so the organic C in the soils were not in equilibrium (due to previous changes in land use/management) when first measured in 1980 and continued to decrease until they were measured again between 1995 – 2003.

7.3.7 Category-Specific Recalculations

There is no change in the overall net GHG source in category 5B between 1990 and 2009 (**Figure 7-5**). There is a small change of 2% in 2010 with the updating of the activity data for agricultural liming (the 2010 values were published too late for inclusion in the 2010 inventory). Other small changes in emissions are described in **Table 7-4**.

Figure 7-5 5B Cropland change in net emissions between 2010 and 2011 inventory

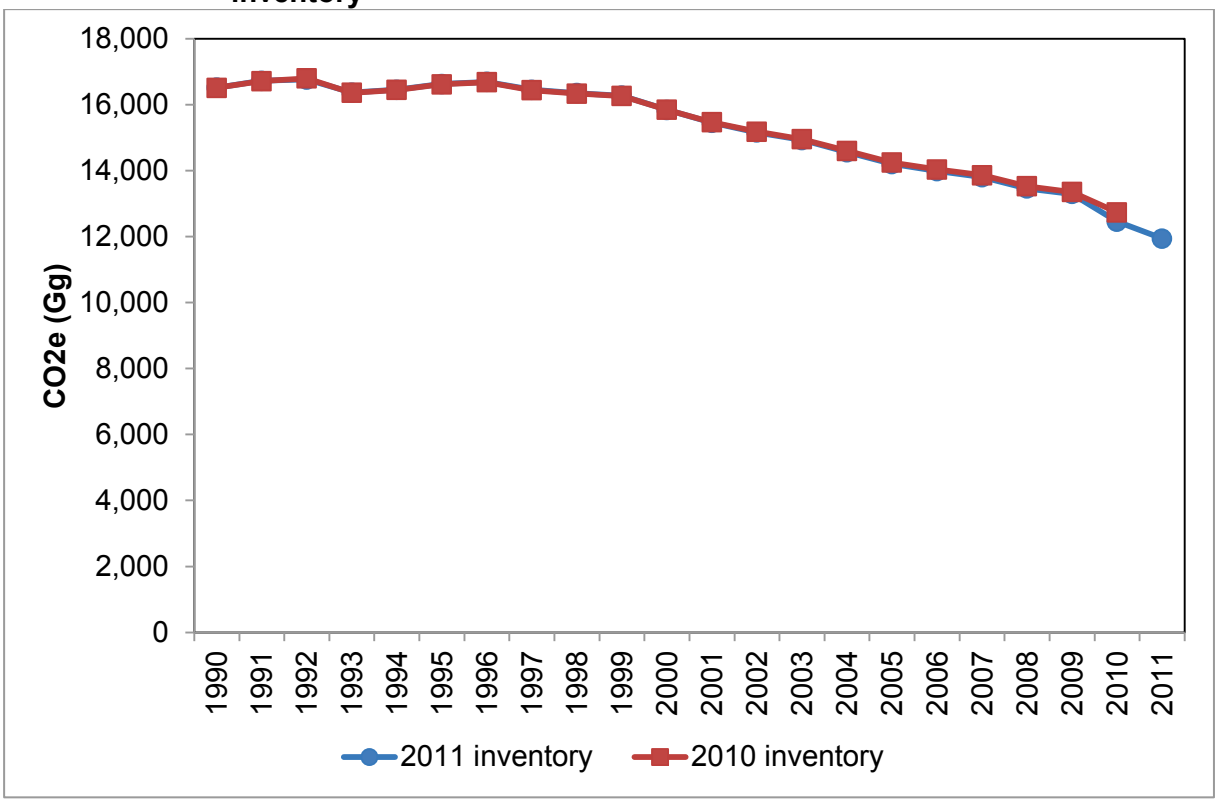


Table 7-4 5B Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
5B1/5(IV)	CO_2 emissions from agricultural lime application	831.57	486.12	831.73	429.59	Gg CO_2	Adjustment of grass/cropland split for liming
5B1/5(V)	Biomass burning/Wildfires	NA	NA	0.00	NO	Gg CH_4	New wildfire activity data. Carbon is assumed to be replaced by regrowth within a single year
5B1/5(V)	Biomass burning/Wildfires	NA	NA	0.00	NO	Gg N_2O	New wildfire activity data. Carbon is assumed to be replaced by regrowth within a single year
5B2	Carbon stock change in living biomass/Loss	-66.08	-36.94	-66.59	-4.91	Gg C	Biomass and DOM losses following deforestation are now estimated from country-specific biomass densities. Correction of error in 2010 inventory (Settlements converted to Cropland)
5B2	Net carbon stock change in dead organic matter	IE	IE	-0.05	-0.13	Gg C	Biomass and DOM losses following deforestation are now estimated from country-specific biomass densities
5B2	Net carbon stock change in mineral soils	-3108.74	-1674.43	-3108.74	-1663.62		Adjustment of time series in activity data
5B2/5(III)	N_2O emissions from disturbance associated with LUC to Cropland	2.52	2.01	2.48	1.77	Gg N_2O	Minor adjustment in activity data
5B2/5(V)	Biomass burning/Controlled burning	1.49	4.31	1.07	2.40	Gg CO_2	Biomass and DOM losses following deforestation are now estimated from country-specific biomass densities
5B2/5(V)	Biomass burning/Controlled burning	0.01	0.02	0.00	0.01	Gg CH_4	Biomass and DOM losses following deforestation are now estimated from country-specific biomass densities
5B2/5(V)	Biomass burning/Controlled burning	0.00	0.00	0.00	0.00	Gg N_2O	Biomass and DOM losses following deforestation are now estimated from country-specific biomass densities

7.3.8 Category-Specific Planned Improvements

An inventory development project (SP1113), with a focus on soil carbon the impacts of cropland and grassland management on soil carbon, has been funded by the UK's Department of Environment, Food and Rural Affairs. The key objectives of the project are:

- The development of an operational framework for reporting soil carbon stock changes from agricultural land management;
- The compilation of appropriate activity data for reporting at Tier 1 and/or Tier 2 levels;
- The integration of research on the impacts of land management on soil carbon stock change into a comprehensive "database" that will allow the elucidation of country-specific emission factors for the key land management activities in the UK; and
- The extension of estimates of soil carbon stock change into the future, in order to investigate the impact of policies, both for mitigation and other ambitions, such as energy/food security and the maintenance of biodiversity.

The methodologies will be compatible with the current LULUCF inventory reporting system, and will be integrated into annual inventory reporting after the project completion (2014). A range of Business As Usual and mitigation scenarios will be developed to investigate the potential for climate change mitigation from cropland and grassland management to 2020 and 2050. These will be applied using the methodology already developed for the 1990-2010 reporting and by Tier 3 ensemble modeling, and the results will be assessed for the mitigation potential and interacting impacts in different regions of the UK.

The results of the project will be used to improve the LULUCF inventory reporting and projections. This will better reflect the impacts of land management on GHG emissions and removals, enabling the analysis of the impact of specific policies in this area and progress in achieving climate change mitigation targets.

7.4 CATEGORY 5C – GRASSLAND

7.4.1 Description

Emissions sources	5C Grassland: carbon stock change 5C Grassland: CO_2 emissions from agricultural lime application 5C Grassland: 5(V) Biomass burning
Gases Reported	CO_2, CH_4, N_2O
Methods	T3 for carbon stock changes, T1 for other emissions
Emission Factors	Country-specific for T3 methods
Key Categories (Trends)	None identified
Key Categories (Level)	5C (CO_2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.

Major improvements since last submission	Inclusion of new activities (biomass burning emissions from non-forest wildfires)

The category is disaggregated into 5.C.1 Grassland remaining Grassland and 5.C.2 Land converted to Grassland. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland.

Carbon stock changes in soils arising from historical land use change to Grassland more than 20 years before the inventory reporting year are reported under 5.C.1. The area of undisturbed grassland (8,561.48 kha in 2011) is also reported here, although no emissions are associated with this area, so that the total area of grassland matches that reported in the annual agricultural census.

Carbon stock changes and biomass burning emissions due to the conversion of other land categories to Grassland in the 20 years before the inventory reporting year are reported under 5.C.2 (biomass burning emissions occur in the same year as the land use conversion). All forms of land use change, including deforestation, are considered and both mineral and organic soils are included.

Emissions of carbon dioxide from the application of limestone, chalk and dolomite to grassland are reported in Table 5(IV). The amount of agricultural lime applied relates to all areas of Grassland, therefore it will include areas in 5C1 and 5C2.

Emissions of CO_2, CH_4 and N_2O from the burning of forest biomass when Forest Land is converted to Grassland are reported under Table 5(V). Emissions from wildfires on grassland are reported for the first time in this inventory. Full details of the method and activity data are given in **Annex 3.7**.

The data reported for the UK in Sectoral Table 5 in the Information item “Grass Land converted to other Land-Use Categories” includes both changes in carbon stock in biomass and soils under “Net CO_2 emissions/removals”.

7.4.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The approaches used for representing land use areas in the inventory are described in **Section 7.3.2**. The areas of Grassland receiving lime are estimated from the pasture grassland (short term (<5 years old) and permanent (>5 years old)) area reported in the annual June Agricultural Census and the proportion of grassland receiving lime reported in the British Survey of Fertiliser Practice (2011).

Areas of Forest Land converted to Grassland (deforestation) are estimated from unconditional felling licence data from the Forestry Commission and land conversion ratios from Countryside Survey. The area of unconditional felling licences (felling licences granted without a requirement to restock) in England (1992-present), Scotland (1998-present) and Wales (1996-present) is used to estimate deforestation to rural land uses (available at http://www.forestry.gov.uk/datadownload). Countryside Survey (CS) data (1990-2007) is used to fill gaps in the time series and to estimate deforestation in Northern Ireland (where no suitable activity data is available). Details are given in **Annex 3.7**.

7.4.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Grassland is defined in accordance with the Good Practice Guidance (IPCC 2003). Grazing is the pre-dominant land use, so areas of wetland habitat not used for peat extraction, such as bogs, are also included in the Grassland category. For pre-1980 land use matrices grassland is the sum of the following land cover types in the Monitoring Landscape Change project (MLC 1986): upland heath, upland smooth grass, upland coarse grass, blanket bog, bracken, lowland rough grass, lowland heather, gorse, neglected grassland, marsh, improved grassland, rough pasture, peat bog, fresh marsh and salt marsh. Post-1980, grassland is the sum of the following Broad Habitat types in the Countryside Survey: improved grassland, neutral grassland, calcareous grassland, acid grassland, bracken, dwarf shrub heath, fen/marsh/swamp, bogs and montane (**Table 7-5**).

Table 7-5 Definitions of Broad Habitat types within the Grassland category (from Haines-Young *et al*. 2000, Appendix A).

Broad habitat type	Definition
Improved grassland	*Improved Grassland* occurs on fertile soils and is characterised by the dominance of a few fast growing species, such as rye-grass and white clover. These grasslands are typically used for grazing and silage, but they can also be managed for recreational purposes. They are often intensively managed using fertiliser and weed control treatments, and may also be ploughed as part of the normal rotation of arable crops but if so, they are only included in this Broad Habitat type if they are more than one year old.
Neutral grassland	*Neutral Grasslands* are found on soils that are neither very acid nor alkaline. Unimproved or semi-improved *Neutral Grasslands* may be managed as hay meadows, pastures or for silage. They differ from *Improved Grassland* in that they are less fertile and contain a wider range of herb and grass species
Calcareous grassland	Vegetation dominated by grasses and herbs on shallow, well-drained soils, which are alkaline, as a result of the weathering of chalk, limestone or other types of base-rich rock.
Acid grassland	Vegetation dominated by grasses and herbs on a range of lime-deficient soils which have been derived from acidic bedrock or from superficial deposits such as sands and gravels.
Bracken	Stands of vegetation greater than 0.25 ha in extent which are dominated by a continuous canopy cover (>95% cover) of bracken (*Pteridium aquilinum*) at the height of the growing season.
Dwarf shrub heath	*Dwarf Shrub Heath* comprises vegetation that has a greater than 25% cover of plant species from the heath family or dwarf gorse species. It generally occurs on well-drained, nutrient poor, acid soils.
Fen, marsh and swamp	This habitat occurs on ground that is permanently, seasonally or periodically waterlogged as a result of ground water or surface run-off. It can occur on peat, peaty soils, or mineral soils. It covers a wide range of wetland vegetation, including fens, flushes, marshy grasslands, rush-pastures, swamps and reedbeds.
Bog	Wetlands that support vegetation that is usually peat-forming and which receive mineral nutrients principally from precipitation rather than ground water. Where bogs have not been modified by surface drying and aeration or heavy grazing the vegetation is dominated by plants tolerant of acid conditions.
Montane habitats	Vegetation types that occur exclusively above the former natural tree-line on mountains. It includes prostrate dwarf shrub heath, snow-bed communities, sedge and rush heaths, and moss heaths.

7.4.4 Methodological Issues

A summary of the land use matrix approach used to estimate changes in biomass and soil carbon due to land use change is given in **Section 7.3.4**. Fluxes arising from land use change in the 20 years before the inventory year are reported under 5C2 Land converted to Grassland. Fluxes from historical land use change (more than 20 years before the inventory year) are reported under 5C1 Grassland remaining Grassland. Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.7**.

7.4.5 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5C Grassland was estimated to have an uncertainty of 52% for net emissions in 1990 and 2009 (assumed to continue to 2011) (slightly lower than the previous assessment of 55%). The uncertainty analysis (see **Annex 3.7.13**) has been extended to encompass the whole of the existing inventory methodology, applying uncertainty quantification more widely and rigorously to all model parameters and empirical conversion factors, and to quantify the impact of those uncertainties on the inventory.

The areas undergoing land use change are the biggest source of uncertainty in the LULUCF inventory, but model choice and soil carbon parameters are also significant. Work on assimilating more land use data sets is planned for 2012-2014, which should constrain the high uncertainties associated with areas of land use change.

For liming, uncertainty in both the activity data and emission factor are judged to be low. The main source of uncertainty in the estimates is caused by non-publication of some data due to commercial restrictions although these are not judged to be very significant.

The wildfire activity data are estimated to have an uncertainty of 50% for 2010-2011 and 100% for 1990-2009, as these years have been extrapolated. The IPCC default of 70% uncertainty is used for the emission factors.

In terms of time series consistency:

- For liming (5C) there is good time series consistency as there has been continuity in the published data sources.
- For changes in non-forest biomass and soil carbon stocks due to land use change the data sources for Great Britain have separate good internal consistency. Consistency between these and Northern Ireland data sources has improved with better methodological integration between land use surveys.
- For emissions due to biomass burning after conversion of Forest Land to Grassland, the time series consistency has improved to high with the introduction of country-specific data sets
- For emissions from wildfires, a new activity dataset became available for 2010 onwards. Burnt areas have been extrapolated back to 2005 based on remote sensing data, but between 1990 and 2005 there is no appropriate data to use for extrapolation.

7.4.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10**. Research described in **Section 7.3.6** is also relevant to this section.

7.4.7 Category-Specific Recalculations

There have been small changes of ±4% in the overall net GHG sink in category 5C between 1990 and 2010 (**Figure 7-6**). These arise from the inclusion of the new wildfires emissions source (affecting CH_4 and N_2O), and adjustments to the deforestation activity data set (biomass and dead organic matter losses following deforestation are now estimated from country-specific biomass densities). Other small changes in emissions are described in **Table 7-6**.

Figure 7-6 5C Grassland change in net emissions between 2010 and 2011 inventory

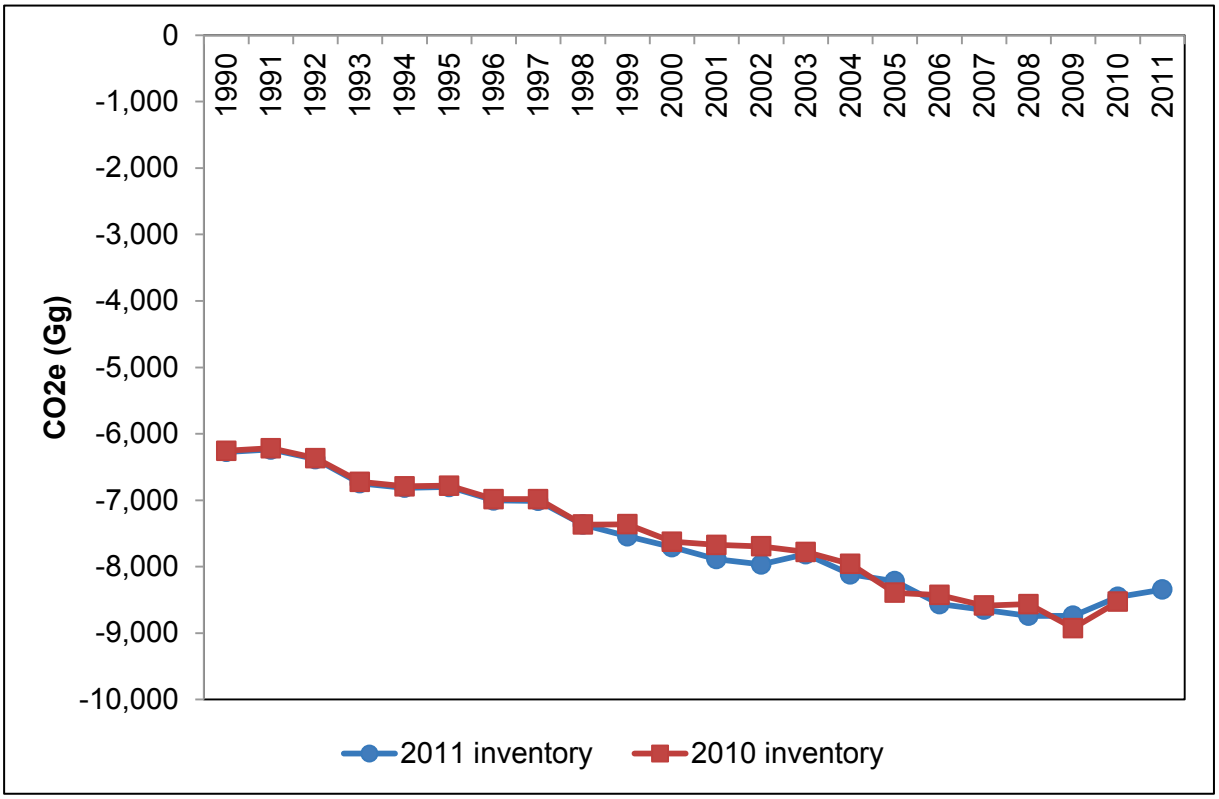


Table 7-6 5C Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
5C1/5(IV)	CO_2 emissions from agricultural liming/	687.97	421.35	688.09	376.29	Gg CO_2	Adjustment of grass/cropland area split for liming
5C1/5(V)	Biomass burning/Wildfires	NE	NE	0.50	0.22	Gg CH_4	New wildfire activity data. Carbon is assumed to be replaced by regrowth within a single year
5C1/5(V)	Biomass burning/Wildfires	NE	NE	0.05	0.02	Gg N_2O	New wildfire activity data. Carbon is assumed to be replaced by regrowth within a single year
5C2	Carbon stock change in living biomass/Loss	-23.92	-72.04	-15.75	-44.09	Gg C	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities.
5C2	Net carbon stock change in dead organic matter	IE	IE	-1.24	-4.48	Gg C	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities.
5C2	Net carbon stock change in mineral soils	1410.08	1243.45	1410.08	1244.30	Gg C	Adjustment of time series in activity data
5C2/5(V)	Biomass burning/Controlled burning	42.58	128.10	27.35	89.46	Gg CO_2	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities.
5C2/5(V)	Biomass burning/Controlled burning	0.19	0.56	0.12	0.39	Gg CH_4	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities.
5C2/5(V)	Biomass burning/Controlled burning	0.00	0.00	0.00	0.00	Gg N_2O	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities.

7.4.8 Category-Specific Planned Improvements

The SP1113 inventory development project described in section 7.3.8 will assess the impact of grassland management on soil carbon in the UK.

Further adjustments to the deforestation activity dataset will be made once finalised estimates of woodland loss from the National Forest Inventory become available (see **section 7.2** for further details). The Forestry Commission is currently undertaking further work to resolve areas of woodland loss to the required scale for reporting. The intention is that eventually deforestation estimates should be obtained directly from periodic National Forest Inventories (NFIs), as results from these become available.

7.5 CATEGORY 5D – WETLANDS

7.5.1 Description

Emissions sources	5D Wetlands: Carbon stock change 5D Wetlands: 5(II) Non-CO_2 emissions from drainage of soils
Gases Reported	CO_2, N_2O
Methods	Tier 1
Emission Factors	Country specific and default EFs
Key Categories (Trends)	None identified
Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Not occurring
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	Improved consistency of land use changes to and from Wetlands

According to the IPCC (2006), Wetlands include any land that is covered or saturated by water for all or part of the year, and that does not fall into the Forest Land, Cropland, or Grassland categories. Managed wetlands are those where the water table is artificially changed (i.e. raised or drained) or those created by human activity. Emissions from unmanaged wetlands are not estimated. Methodologies are provided for peatlands that are cleared and drained for peat production (for energy or horticultural purposes) and for areas converted to permanently flooded land (reservoirs).

In the UK, estimates are made of emissions from on-site peat production and off-site emissions from horticultural peat under 5.D.1 Wetlands remaining Wetlands. A small area of grassland converted to Wetland is included under 5.D.2 Land converted to Wetlands, with the associated soil emissions estimated using the Tier 1 methodology. N_2O emissions from wetland drainage (as part of peat production) are reported under 5.D.2: they should properly be associated with the area in 5.D.1 but the structure of the CRF tables does not allow this.

The area of inland water (164.05 kha) is reported in this category but no emissions are associated with such areas.

7.5.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

A different approach to that used for other land use categories is necessary, as peat extraction sites are not explicitly identified in the habitat/landscape surveys used for the land use matrix. They are most likely to fall under the “Inland rock” broad habitat (5G Other) or “Bog” broad habitat (5C Grassland) if some vegetation cover remains (Maskell *et al*. 2008). We explored a number of data sources for constructing a robust dataset on the location, extent and type of peat extraction in Great Britain and Northern Ireland. Three data sources were then used in combination to produce an activity dataset with areas of active peat extraction.

- The British Geological Survey (BGS) have supplied the set of Great Britain peat extraction site records from the Directory of Mines and Quarries (Cameron et al. 2002, 2008, 2010): this gives location, name, operator and council for currently active commercial extraction sites in England (54), Scotland (23) and Wales (2). This Directory does not record the extent of the extraction area. It is updated regularly but did not report peat extraction before 2002.
- Areas of peat extraction can be clearly seen on Google Earth satellite imagery (using the BGS point locations). Areas can be measured using software such as Feature Manipulation Engine. However, the imagery has been taken at varying (but known) dates and coverage is not consistent across the UK.
- There is good information on peat extraction (for both horticultural and fuel use) in Northern Ireland from papers by Tomlinson (2010) and Cruickshank *et al*. (1995). The research described in these papers was funded by Defra under previous LULUCF inventory development projects.

Most commercial extraction in the UK is undertaken using the vacuum harvesting method. The bare surface of the peat is scarified to 5-10 cm depth, the resulting loose peat is left to dry and then removed. Areas undergoing such extraction are clearly visible on aerial/satellite imagery (**Figure 7-7**). It is inferred that that the areas of existing extraction do not vary in extent from year to year. If a site could not be identified on the Google Earth imagery then it was not included (some areas may not actually be undergoing extraction, or the photographs may not be up-to-date).

Figure 7-7 Peat extraction site visible on Google Earth imagery

7.5.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Peatlands managed for peat extraction are defined as those sites currently registered for commercial extraction where extraction activity is visible on recent aerial/ satellite photographs or by field visits. Peat extraction for domestic use occurs in Northern Ireland and Scotland in the UK. Peat cuttings for domestic extraction are not clearly identifiable on aerial photographs, and ground survey would probably be required to estimate the extent of such activity. This has been done for Northern Ireland but no such work has been undertaken for Scotland.

The area of inland water is taken from the "UK Standard Area Measurements" (ONS 2010). It defines inland water as 'bounded' permanent water bodies, e.g. lakes, lochs and reservoirs, exceeding 1 km^2 (100 hectares) in area. 'Open' tracts of water, e.g. rivers, canals and streams are excluded from this definition.

7.5.4 Methodological Issues

Emissions for this category have been developed on the basis of the Tier 1 default methodology, which does not distinguish between peat extraction production phases (i.e. it includes conversion and vegetation clearing). On-site emissions associated with peat extraction are reported under 5.D.1 Wetlands remaining Wetlands. All carbon in horticultural peat is assumed to be emitted off-site during the extraction year. Methane emissions are assumed to be insignificant but N_2O emissions from drainage are reported (although emissions are considered insignificant on nutrient-poor peatlands). The latest Directory of Mines and Quarries categorises sites as producing horticultural or energy source (fuel) peat. This information is now used to extract the area of nutrient-rich peats that will produce N_2O emissions (following the IPCC Tier 1 methodology). Further information is given in **Annex 3.7**.

A small area of land conversion to Wetlands occurs between 2003 and 2005, which is assumed to be all from Grassland (based on the examination of Google Earth imagery). This area and the associated on-site emissions are reported under 5D.2 Land converted to Wetlands, using the 5 year transition period recommended by the IPCC 2006 Guidelines.

The site records show that the area under active peat extraction diminished between 1990 and 2002 for Great Britain and 1991 and 2007 for Northern Ireland. Some areas show no change on the Google Earth imagery, and are assumed to be abandoned extraction sites that are still producing emissions (reported under 5D1). Sites in Northern Ireland and sites in Great Britain where extraction is no longer visible on the Google Earth imagery are assumed to have been converted to Grassland. Changes in biomass carbon and organic soil carbon from this land use change are reported using the Tier 1 approach from the IPCC 2006 Guidelines. In the 2010 inventory, the area that was no longer recorded as being under active extraction was reported under the 5F2.4 Wetland converted to Other Land category, but the new approach is more robust and produces a more consistent land use change matrix.

7.5.5 Uncertainties and Time-Series Consistency

Uncertainties for the activity data are estimated to be >100% in 1990 and 50% in 2009. Uncertainties in the emission factors are the default IPCC values given in the 2006 Guidelines: -100% to 315% for peat extracted for horticultural use and -98% to 600% for peat extracted for fuel use.

Time series consistency for activity data is medium as the time series is based upon interpolation between survey dates.

7.5.6 Category-Specific QA/QC and Verification

The activity dataset developed was partially verified by comparing the measured areas with reported areas of planning permission (which were available for some extraction sites in England and Scotland). The measured areas either matched or were smaller than the planning permission areas, which is to be expected as it is known that not all areas with planning permission are undergoing active extraction.

7.5.7 Category-Specific Recalculations

There has been no change in the overall net GHG source in category 5D between 1990 and 2008 (**Figure 7-8**). The activity data for 2009-2010 was updated with the latest published information on peat volume sales (ONS 2011). Volumes for 2011 were assumed to be equal to those in 2010. Other small changes in emissions are described in **Table 7-7**.

Figure 7-8 5D Wetlands change in net emissions between 2010 and 2011 inventory

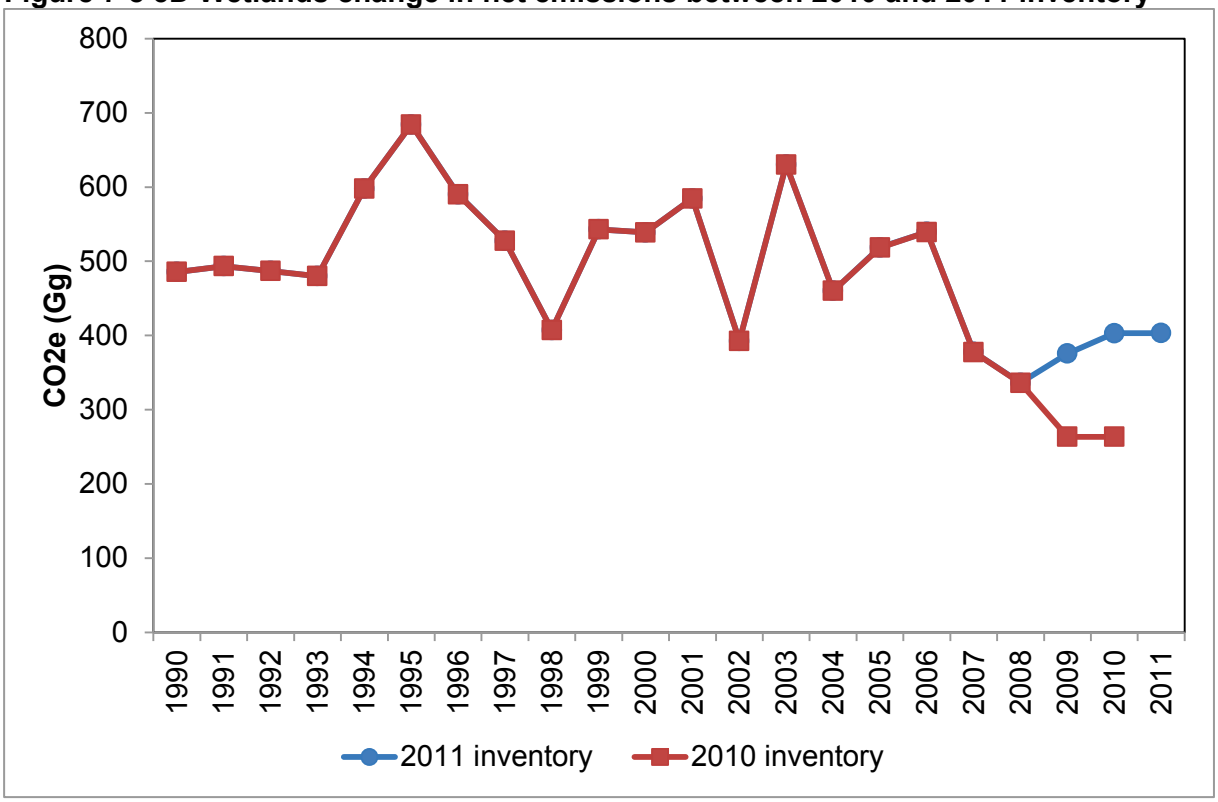


Table 7-7 5D Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2012 submission		2013 submission		Units	Comment/Justification
		1990	2010	1990	2010		
5D1	Net carbon stock change in soils	-131.38	-71.73	-131.38	-109.80	Gg C	Extraction sites that are no longer active are assumed to be still producing on-site emissions. 2009-2010: new activity data published
5D2	Net carbon stock change in soils	IE	IE	NO	-0.00		Conversion of Grassland to Wetland now included (does not occur throughout the time series)
5D2/5(II)	Non-CO_2 emissions from drainage	0.01	0.00	0.01	0.00	Gg N_2O	Extraction sites that are no longer active are assumed to be still producing on-site emissions

7.5.8 Category-specific planned improvements

None planned, but this category will be re-examined when the latest IPCC guidance becomes available in late 2013.

7.6 CATEGORY 5E – SETTLEMENTS

7.6.1 Description

Emissions sources	5E Settlements: Carbon stock change 5E Settlements: 5(V) Biomass burning
Gases Reported	CO_2, CH_4, N_2O
Methods	T3 for carbon stock changes, T1 for other emissions
Emission Factors	Country-specific for T3 methods
Key Categories (Trends)	None identified
Key Categories (Level)	5E (CO_2)
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	None

This category is disaggregated into 5.E.1 Settlements remaining Settlements and 5.E.2 Land converted to Settlements. Reporting of carbon stock changes is disaggregated between the four geographical areas of England, Scotland, Wales and Northern Ireland.

Carbon stock changes in soils arising from historical land use change to Settlements more than 20 years before the inventory reporting year are reported under 5.E.1. Carbon stock changes and biomass burning emissions due to conversion of Forest Land to Settlements in the previous 20 years before the reporting year are reported under category 5.E.2 (biomass burning emissions occur in the same year as the land use conversion). All forms of land use change, including deforestation, are considered and both mineral and organic soils are included.

Emissions of CO_2, CH_4 and N_2O from the burning of forest biomass when Forest Land is converted to Settlement are reported under Table 5(V).

7.6.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The approaches used for representing land use areas in the inventory are described in **Section 7.3.2**. Activity data on areas of Forest Land converted to Settlement (deforestation) is extrapolated from data for England held by the Department of Communities and Local

Government (DCLG). They obtain this information from the Ordnance Survey (the national mapping agency) which makes an annual assessment of land use change from the data it collects for map updating. Areas of Forest Land conversion to Settlement are calculated as the sum of all forest land use categories to urban land use categories. (Note that this data set is not thought to be reliable for forest conversion in rural areas because the resurveying frequency is too low). Land conversion ratios from Countryside Survey are used for the extrapolation from England to the other countries in the UK. Details are given in **Annex 3.7**

7.6.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Settlement is defined in accordance with the Good Practice Guidance (IPCC 2003). For pre-1980 land use matrices Settlement land is the sum of the Built-up, Urban open, Transport, Mineral workings and Derelict land cover types in the Monitoring Landscape Change project (MLC 1986). Post-1980, Settlement land corresponds to the "Built-up and Gardens" and "Boundary and linear features" Broad Habitat types in the Countryside Survey (Haines-Young *et al*. 2000, Appendix A), defined as:

Built-up and Gardens: "Covers urban and rural settlements, farm buildings, caravan parks and other man-made built structures such as industrial estates, retail parks, waste and derelict ground, urban parkland and urban transport infrastructure. It also includes domestic gardens and allotments."

Boundary and linear features: "a diverse range of linearly arranged landscape features such as hedgerows, walls, stone and earth banks, grass strips and dry ditches. This habitat type also includes some of the built components of the rural landscape including roads, tracks and railways and their associated narrow verges of semi-natural habitat."

Some components of the "Boundary and linear features" Broad Habitat type could fall under the definition of Cropland or Grassland. It is not possible to disaggregate this Broad Habitat further and the assignment to a single land use category avoids double-counting. In the latest 2007 Countryside Survey the "Boundary and linear features" Broad Habitat type covered 2% of the UK land area.

7.6.4 Methodological Issues

A summary of the land use matrix approach used to estimate changes in biomass and soil carbon due to land use change is given in **Section 7.3.4**. Fluxes arising from land use change in the 20 years before the inventory year are reported under 5E2 Land converted to Settlement. Fluxes from historical land use change (more than 20 years before the inventory year) are reported under 5E1 Settlement remaining Settlement. Detailed descriptions of the methods and emission factors used for the activities in this Category can be found in **Annex 3.7**.

7.6.5 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to the GPG source category and gas. 5E Settlement was estimated to have an uncertainty of 52% for net emissions in 1990 and 2009 (assumed to continue to 2011) (slightly higher than the previous assessment of 50%). The uncertainty analysis (see **Annex 3.7.13**) has been extended to encompass the whole of the existing inventory methodology, applying uncertainty quantification more widely and rigorously to all model parameters and empirical conversion factors, and to quantify the impact of those uncertainties on the inventory.

The areas undergoing land use change are the biggest source of uncertainty in the LULUCF inventory, but model choice and soil carbon parameters are also significant. Work on assimilating more land use data sets is for 2012-2014, which should constrain the high uncertainties associated with area.

In terms of time series consistency:

- For changes in non-forest biomass and soil carbon stocks due to land use change the data sources for Great Britain have separate good internal consistency. Consistency between these and Northern Ireland data sources has improved with better methodological integration between land use surveys.
- For emissions due to biomass burning after conversion of Forest Land to Settlement, there is good time series consistency as there has been continuity in the activity data source.

7.6.6 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10**. Research described in **Section 7.3.6** is also relevant to this section.

7.6.7 Category-Specific Recalculations

There has been a 1% reduction in the size of the overall net GHG source in category 5E between the 2010 and the 2011 inventories (**Figure 7-9**). These arise from adjustments to the deforestation activity data set (biomass and dead organic matter losses following deforestation are now estimated from country-specific biomass densities). Other small changes in emissions are described in **Table 7-8**.

Figure 7-9 5E Settlements change in net emissions between 2010 and 2011 inventory

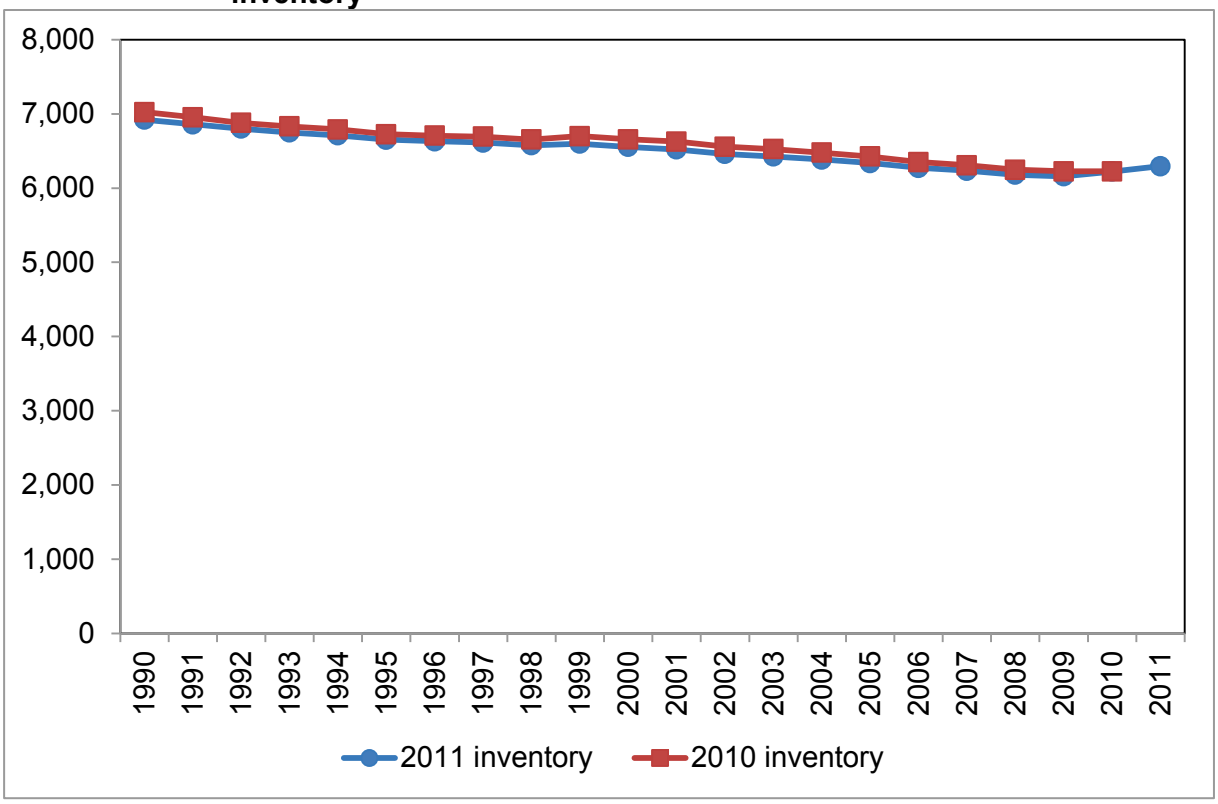


Table 7-8 5E Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
5E2	Carbon stock change in living biomass/Losses	-50.22	-42.36	-30.41	-31.18	Gg C	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities
5E2	Net carbon stock change in dead organic matter	IE	IE	-3.34	-3.60	Gg C	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities
5E2	Net carbon stock change in soils	-1381.05	-971.70	-1381.05	-984.92	Gg C	Adjustment in time series of activity data
5E2/5(V)	Biomass burning	108.70	90.52	72.50	73.89	Gg CO_2	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities
5E2/5(V)	Biomass burning	0.47	0.40	0.32	0.32	Gg CH_4	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities
5E2/5(V)	Biomass burning	0.00	0.00	0.00	0.00	Gg N_2O	Biomass and DOM losses following deforestation are now estimated using country-specific biomass densities

7.6.8 Category-Specific Planned Improvements

Further adjustments to the deforestation activity dataset will be made once finalised estimates of woodland loss from the National Forest Inventory become available (see **Section 7.2** for further details). The Forestry Commission is currently undertaking further work to resolve areas of woodland loss to the required scale for reporting. The intention is that eventually deforestation estimates should be obtained directly from periodic National Forest Inventories (NFIs), as results from these become available.

7.7 CATEGORY 5F – OTHER LAND

7.7.1 Description

Emissions sources	None
Gases Reported	None
Methods	N/A
Emission Factors	N/A
Key Categories (Trends)	None identified
Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Areas reported under the relevant Sector 5 sub-categories at Tier 1
Completeness	No known omissions- areas are reported for land uses with no associated emissions.
Major improvements since last submission	Improved consistency in the land use change matrix

No emissions or removals are reported in this category. It is assumed that there are very few areas of land of other types that become bare rock or water bodies, which make up the majority of this type. Therefore Table 5.F. (Other Land) is completed with 'NO' (Not Occurring).

7.7.2 Information on approaches used for representing land areas and on land use databases used for the inventory preparation

The approaches used for representing land use areas in the inventory are described in **Section 7.3.2**.

7.7.3 Land-use definitions and the classification system used and their correspondence to the LULUCF categories

Other Land is defined as areas that do not fall into the other land use categories. For pre-1980 land use matrices Other Land is the sum of the Bare rock, Sand/shingle, Inland water and Coastal water land cover types in the Monitoring Landscape Change project (MLC 1986). Post-1980, Other Land contains the Inland rock, Standing water and Canals and Rivers and Streams Broad Habitat types in the Countryside Survey (**Table 7-9**). As described

in **section 7.5**, areas of inland water exceeding 1km^2 are included in 5D Wetlands, but water bodies below this threshold would still be included under Other Land.

Table 7-9 Definitions of Broad Habitat types included in Other Land (Haines-Young *et al*. 2000, Appendix A)

Broad habitat type	Definitions
Inland rock	Habitat types that occur on both natural and artificial exposed rock surfaces, such as inland cliffs, caves, screes and limestone pavements, as well as various forms of excavations and waste tips, such as quarries and quarry waste.
Standing Waters and Canals	This Broad Habitat category includes lakes, meres and pools, as well as man-made water bodies such as reservoirs, canals, ponds, gravel pits and water-filled ditches.
Rivers and Streams	This category includes rivers and streams from bank top to bank top; where there are no distinctive banks or banks are never overtopped, it includes the extent of the mean annual flood.

7.7.4 Category-specific planned improvements

None in this category.

7.8 CATEGORY 5G – OTHER

7.8.1 Description

Emissions sources	5G Other (Harvested Wood Products)
Gases Reported	CO_2
Methods	Tier 3
Emission Factors	Country-specific
Key Categories (Trends)	None identified
Key Categories (Level)	None identified
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Reported under the relevant Sector 5 sub-categories at Tier 3
Completeness	No known omissions
Major improvements since last submission	None

Changes in stocks of carbon in harvested wood products (HWP) are reported here. These HWP stocks result from normal forest management processes (thinning and harvesting) and from conversion of Forest Land to Cropland, Grassland or Settlements (deforestation), as recommended by a previous ERT.

7.8.2 Methodological Issues

A description of the method used to account for changes in stocks of carbon in HWP is in **Annex 3.7**. The carbon accounting model (C-Flow) is used to calculate the net changes in carbon stocks of harvested wood products, in the same way as it is used to estimate carbon

stock changes in 5.A. Changes in carbon stocks from HWP arising from deforestation (conversion of Forest Land to Grassland or Settlement) are estimated using a look-up table of annual HWP stock changes generated by C-Flow.

7.8.3 Uncertainties and Time-Series Consistency

The uncertainty analysis in the Annexes provides estimates of uncertainty according to IPCC source category and gas. 5G was previously estimated to have an uncertainty of 30% for net emissions in 1990 and 2010. The latest uncertainty analysis estimated uncertainty of more than 22% for this category (in line with the uncertainty for 5A Forest Land with an additional unknown uncertainty for the HWP decay term), which is in line with the continued use of the 30% estimate.

Activity data (areas planted and consequently harvested) are obtained consistently from the same national forestry sources, which helps ensure time series consistency of estimated removals.

7.8.4 Category-Specific QA/QC and Verification

This source category is covered by the general QA/QC procedures, which are discussed in **Section 7.10** Work continues to verify the modelled Harvested Wood Products estimates by comparison with the Forestry Commission model forecasts.

7.8.5 Category-Specific Recalculations

Minor revisions in the deforestation activity dataset resulted in changes in the pool of harvested wood products (from additions from deforestation) (**Figure 7-10** and **Table 7-10**).

Figure 7-10 5G Other (Harvested Wood products) change in net emissions between 2010 and 2011 inventory

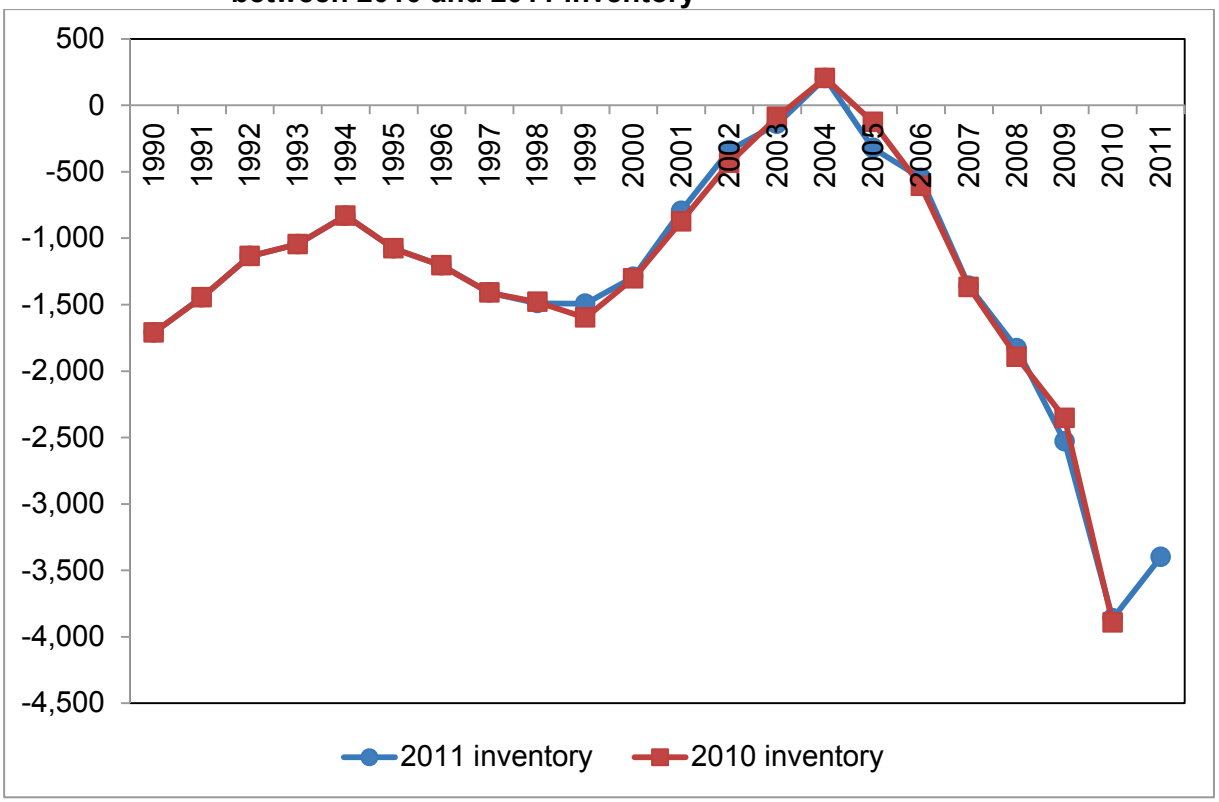


Table 7-10 5G Category specific recalculations to activity data since previous submission

IPCC Category	Source Name	2012 submission 1990	2012 submission 2010	2013 submission 1990	2013 submission 2010	Units	Comment/Justification
5G	Harvested Wood Products	-1710.68	-3894.51	-1710.68	-3862.89	Gg CO_2	Minor adjustment in activity data

7.8.6 Category-Specific Planned Improvements

The emission factors and activity data for harvested wood products will be kept under review. Work is proceeding to ensure the approach for estimating removals and emissions due to HWP are consistent with methodologies agreed at Cancun and Durban and that underpinning data on UK wood production are reported so as to support implementation of these methodologies.

7.9 LULUCF EMISSIONS AND REMOVALS IN THE OVERSEAS TERRITORIES AND CROWN DEPENDENCIES

The UK includes direct GHG emissions in its GHG Inventory from those UK Crown Dependencies (CDs) and Overseas Territories (OTs) which have joined, or are likely to join, the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol. Currently, these are: Guernsey, Jersey, the Isle of Man, the Falkland Islands, the Cayman Islands, Bermuda, Montserrat and Gibraltar. The OTs and CDs were contacted for any updates in datasets in 2011 and a web search of statistical publications was undertaken in 2012. This work builds on an MSc project to calculate LULUCF net emissions/removals for the OTs and CDs undertaken during 2007 (Ruddock 2007). Net emissions/removals from the OTs/CDs are reported under the relevant sub-categories of Sector 5.

Crown Dependencies

Emissions and removals have been calculated using a Tier 1 method in most cases, with a Tier 3 method for forestry in the Isle of Man and Guernsey also being used.

Similar climate and land management parameters are assumed as for the UK. Land areas have been interpolated between land area surveys in some cases. More detailed activity data allowed a Tier 3 method to be applied for forestry in the Isle of Man and Guernsey.

For Jersey, net emissions of GHGs from LULUCF were updated for the 1990 to 2011 inventory, using updated activity data, and ensuring the Tier 1 methodology was applied consistently. The LULUCF sector in Jersey is a small sink, due to conversion to Grassland.

For the Isle of Man, net emissions of GHGs from LULUCF were updated for the 1990 to 2011 inventory, using updated activity data, and ensuring the Tier 1 methodology (for non-forest land use) was applied consistently. The LULUCF sector in the Isle of Man was a net source of CO_2 in 1990 but an increasing net sink since 1996, due to forest land and grassland.

For Guernsey, net emissions of GHGs from LULUCF were updated for the 1990 to 2011 inventory, using updated activity data, and ensuring the Tier 1 methodology was applied consistently. Carbon stock changes due to afforestation were also modelled using the Tier 3 CFlow model. The LULUCF sector in Guernsey is a small source, due to conversion to and liming of Cropland.

Overseas territories

Data were only available to estimate emissions from the Falklands.

More information on the methods are included in the main chapters of the NIR (Section 7.1).

Net emissions of GHGs from LULUCF were updated for the 1990 to 2011 inventory, using updated activity data from the Falkland Islands, and ensuring the Tier 1 methodology was applied consistently. The Falkland Islands are a small source due to land conversion on organic soils. Overall there is very little land use change on the islands (93% of their area is natural Grassland).

7.10 GENERAL COMMENTS ON QA/QC

The Centre for Ecology and Hydrology (the inventory compiler for the LULUCF sector) has adopted the quality assurance principles set out in the Joint Code of Practice for Research issued by the Biotechnology and Biological Sciences Research Council, the Department for Environment, Food and Rural Affairs, the Food Standards Agency and the Natural Environment Research Council. Quality Assurance is reported to Executive Board as appropriate. In addition projects are managed through Prince2 protocols. The CEH Policy Statement is given below.

- CEH is dedicated to achieving and maintaining the highest possible standards of quality in order to meet the needs of its work programmes and the needs of internal and external customers
- In pursuit of its quality aims, CEH strives to create a working situation that enables all staff to contribute to the continuous and meaningful improvement of a Quality Management System through competence and effective communication
- It is the aim to ensure that all staff at CEH understand and are committed to their individual and collective responsibilities for quality
- To achieve these objectives, the suitability of working practices and the training needs for existing and new members of staff will be appraised by management.

Forest Research (project partner) is ISO-14001 qualified and carries out its work in accordance with the Joint Code of Practice for Research described above.

In 2009 the LULUCF inventory project was audited by an independent CEH team to confirm compliance with the Joint Code of Practice, where the project was praised for its high standards.

In addition to internal quality assurance procedures the submitted inventory data is also checked by Ricardo-AEA (the national inventory compilers) and the European Commission.

A Microsoft Access 2007 database is now used to compile all the LULUCF inventory numbers and associated data. This database is used to produce consistent outputs for the CRF and other national and international reporting requirements, and for archiving purposes. The project maintains a publicly available website, http://ecosystemghg.ceh.ac.uk/ where the inventory reports and tables are made available. This website is currently undergoing redevelopment. The inventory data is also made available via the CEH Information Gateway http://gateway.ceh.ac.uk/. Technical information on the inventory methods is documented in a 'wiki' available to team members, ensuring continuity. Issue management software is used for project management and tracking issues such as requests for data from stakeholders and external parties.

8 Waste (CRF Sector 6)

8.1 OVERVIEW OF SECTOR

IPCC Categories Included	6A: Solid Wate Disposal on Land 6B: Wastewater Handling 6C: Waste Incineration
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2
Key Categories (Trends)	Solid Waste Disposal – CO_2 Wastewater Handling – N_2O
Key Categories (Level)	Solid Waste Disposal – CO_2 Wastewater Handling – N_2O
Key Categories (Qualitative)	None identified
Overseas Territories and Crown Dependencies Reporting	Emissions for 6A and 6B are included as a separate category within 6A and 6B respectively. Emissions from 6C are included within UK MSW incineration and the same EFs are applied.
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5
Major improvements since last submission	6B – Improved completeness through inclusion of new estimates for emissions from industrial waste water treatment.

Emissions from the waste sector contributed 3.1% to greenhouse gas emission in 2011. Emissions consist of CO_2, N_2O and CH_4 from waste incineration, and CH_4 from solid waste disposal on land, and both CH_4 and N_2O from wastewater handling. Overall emissions from the waste sector have decreased by 63% since 1990 and this is mostly due to the implementation of methane recovery systems at UK landfill sites, and reductions in the amount of waste disposed of at landfill sites.

Figure 8-1 Breakdown of total GHG emissions from the Waste sector in 2011

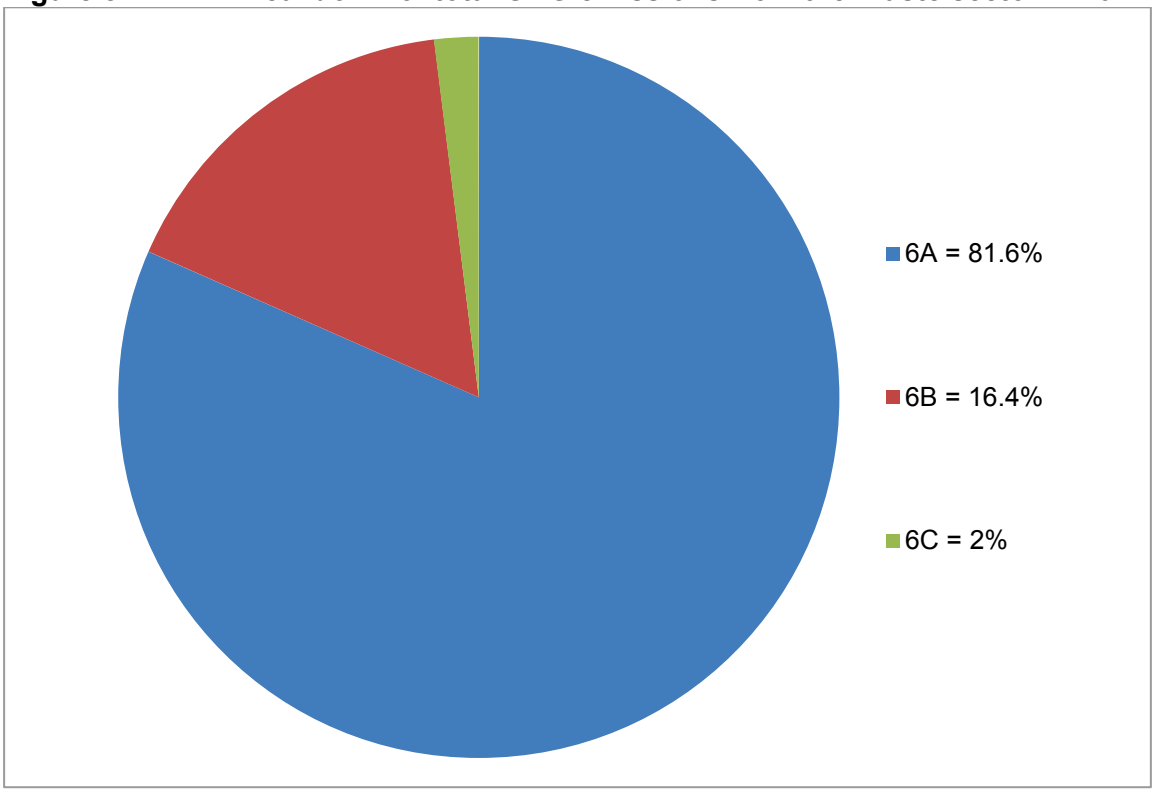
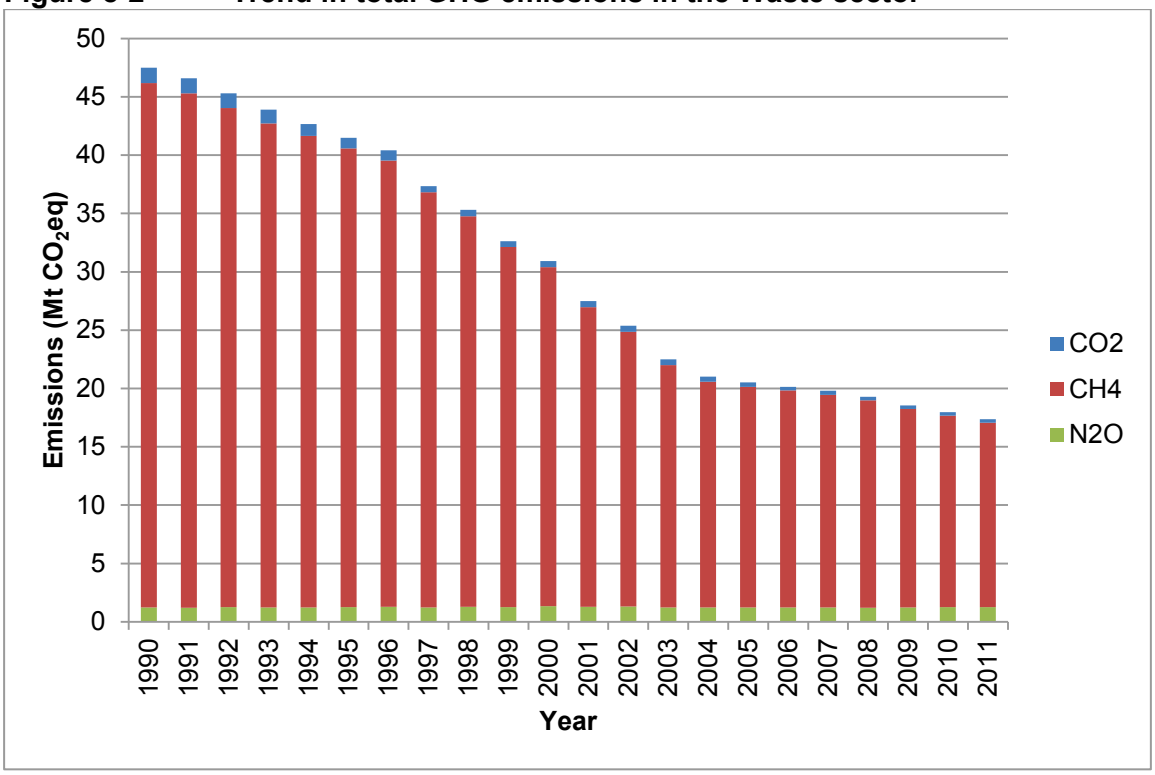


Figure 8-2 Trend in total GHG emissions in the Waste sector



8.2 SOURCE CATEGORY 6A – SOLID WASTE DISPOSAL ON LAND

8.2.1 Source category description

Emissions sources	Sources included	Method	Emission Factors
	6A: Landfill	OTH, T2	CS
Gases Reported	CH_4, NMVOC		
Key Categories (Trends)	Solid Waste Disposal – CH_4		
Key Categories (Level)	Solid Waste Disposal – CH_4		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions for 6A are included as a separate category within 6A.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	None		

The NAEI category "Landfill" maps directly on to IPCC category 6A1 Landfills (managed waste disposal on land) for methane emissions. Emissions are reported from managed landfills that started receiving waste in 1980 and old unmanaged waste disposal sites that closed prior to 1980.

Estimated emissions from this sector in 2011 were 671 kt CH_4. Emissions have been on a downward trend since 1990.

In addition to CH_4, anaerobic decomposition also produces an approximately equivalent amount of carbon dioxide and further CO_2 is also produced by aerobic decomposition processes. However, as the decaying organic matter originates from biomass sources derived from contemporary crops and forests, we do not need to consider the greenhouse impacts of this carbon dioxide. Waste also contains fossil-derived organic matter, predominantly in the form of plastics, but these are essentially non-biodegradable under landfill conditions, and so emissions of fossil-derived CO_2 from SWDS are not considered further. Emissions of carbon dioxide from landfills are therefore reported as "Not Estimated" (NE) as they are considered to be entirely biogenic in origin.

Non-methane volatile organic compounds (NMVOCs) are also released by SWDS. These are estimated using an emission factor relating the NMVOC to the amount of CH_4 emitted. An emission factor of 0.01[38] has been used, which is equivalent to 5.65g NMVOC /m^3 landfill gas (Passant, 1993).

[38] Dimensionless ratio of mass of NMVOC per unit mass of methane.

Nitrous oxide emissions from landfill are believed to be negligible and are not further considered here.

The amount of methane emitted from landfills depends primarily on the amount of biodegradable carbon landfilled and how the sites are operated to reduce the escape of the methane produced from such wastes. Policy measures to reduce methane emissions from landfills have focused on both these aspects. Diverting biodegradable waste away from landfill completely avoids the future formation of methane, but of course landfills continue to produce CH_4 for many years from waste that has already been deposited. Improving the efficiency of gas capture from landfills results in an immediate reduction in emissions, but is by nature an "end of pipe" solution, which does not itself prevent the formation of methane. In practice, a combination of measures based on both reducing the amount of biodegradable waste landfilled and improving the management of sites have, in the UK, provided the foundations for reducing emissions from this source. These two broad approaches are outlined below.

The most important legislative and regulatory measures which have reduced the emissions of methane from UK landfills derive from the 1999 Landfill Directive[39]. The requirements of the Directive were transposed into national legislation through the Landfill (England and Wales) Regulations 2002, subsequently amended in 2004 and 2005 to transpose the requirements of Council Decision 2003/33/EC on Waste Acceptance Criteria. The provisions were re-transposed as part of the Environmental Permitting (England and Wales) Regulations 2010 SI 675, with a number of other revisions and revocations between 2007 and 2012. In Scotland, the Landfill Directive is implemented through the Landfill (Scotland) Regulations 2003, as amended, and in Northern Ireland, through the Landfill Regulations (Northern Ireland) 2003a. The provisions of the Landfill Directive are the drivers for both reducing the amount of biodegradable waste landfilled and in reducing the amount of methane that is released, through improving landfill design, operation and management.

The Waste Framework Directives 2006/12/EC and 2008/98/EC have had an indirect effect on UK landfill sites, by mandating the movement of waste materials up the waste hierarchy – that is, away from landfill disposal and towards more sustainable forms of re-use, recovery, recycling and energy recovery.

8.2.2 Methodological issues

The UK approach to calculating emissions of methane from landfills uses a "Tier 2" methodology based national data on waste quantities, composition, properties and disposal practices over several decades. The equations for calculating methane generation use a first-order decay (FOD) methodology (Revised 1996 IPCC Guidelines[40] p6.10 – 6.11). The IPCC FOD methodology is based on the premise that Dissimilable Degradable Organic Carbon compounds (DDOC)[41] decay under the airless conditions in landfills to form methane, carbon dioxide and a variety of stable decomposition products that remain in the landfill, and represent a sink for carbon. First order means that the rate of reaction is proportional to the amount of reactant (i.e. DDOC) present at any given time. This means that as the reactant is used up, the rate of reaction slows down.

[39] Council Directive 1999/31/EC on the Landfill of Waste. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1999:182:0001:0019:EN:PDF

[40] IPCC, "*Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual,*" 1997

[41] DDOC is the amount of degradable organic carbon (DOC) that is converted (ie dissimilated) to methane and carbon dioxide under landfill conditions. DDOC = DOC x DOC_F where DOC_F is the fraction of DOC that dissimilates.

The Revised 1996 IPCC Guidelines (IPCC, 1997) and Good Practice Guide (IPCC 2000) define the overall approach for calculating methane emission from landfill as the amount of methane (CH_4) generated in the waste, *minus* the amount of methane recovered (for flaring or other combustion process), correcting for the amount of remaining methane that is oxidised to carbon dioxide. This is represented by equation 5.2 of the Good Practice Guide (IPCC 2000).[42]

Mass units used are Giga grams (Gg, 10^9 grams): one Gg is equivalent to one kilotonne (kt).

In the UK model, the various waste types are allocated to three pools (p) of dissimilable degradable organic carbon (DDOC) that decompose according to their characteristic first order rate constant, k_p, which has dimensions of reciprocal time (units in this case are $year^{-1}$). The three pools are described as Rapidly, Moderately, and Slowly Decomposing Organics (RDO, MDO and SDO, respectively). Allocation of DDOC in waste materials to these pools was described in a report produced by Eunomia Consulting and Research (2011), and is summarised in **Table A 3.7.1.1**.

The characteristic decay rates for these three pools are: 0.046 $year^{-1}$ (SDO), 0.076 $year^{-1}$ (MDO) and 0.116 $year^{-1}$ (RDO). These are within the range of 0.030 to 0.200 $year^{-1}$ quoted in IPCC, 2006. Fats, sugars and proteins are assigned to the rapidly degrading pool (RDO), lignin to the slowly degrading pool (SDO) and cellulose, hemicelluloses and remaining compounds are allocated to the moderately degrading pool (MDO).

Methane generation is calculated by equation (1), adapted from IPCC 2000 Equation 5.1:

(1) $$Q_{x,T,t,,p} = L_{x,t,p}\,(e^{-k_p(T-t)}\,(1- e^{-k_p}))$$

Where:

$Q_{x,T,t,p}$ is the amount of methane generated in year T from a unit of waste type x, landfilled in year t, allocated to pool p;
k_p is the first order rate constant of pool p;
$L_{x,t,p}$ is the specific methane potential of waste type x landfilled in year t in pool p, and
e is the exponential constant.

Equation (1) is based on the methodology described in the 2000 Good Practice Guidance (IPCC, 2000) which uses the approach developed for the 1996 Guidelines (IPCC, 1997) with the inclusion of a “normalisation factor” to correct for the small errors introduced into the integration when time is treated as a discrete, as opposed to continuous, variable. This approach has been adopted for previous years’ UK NIRs.

The *specific methane potential* is in turn defined as follows, adapted from notes to IPCC 2000 Equation 5.1:

(2) $$L_{x,t,p} = MCF \,.\, F. \; DDOC_{x,t,p} \,.\, 16/12$$

[42] IPCC, "*IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories,*" 2000

Where

$DDOC_{x,t,p}$ is the dissimilable degradable organic carbon of waste type x assigned to pool p (dimensionless ratio),
F is the molar fraction of methane in landfill gas (dimensionless ratio),
MCF is the Methane Correction Factor (dimensionless ratio) and
16/12 is an adjustment factor to convert mass of carbon to mass of methane.

The total methane generated in each inventory year (T) is then determined by integrating over all waste types (w), all three decomposition pools (p) and all years in which the waste is landfilled (t), adapted from IPCC 2000 Equation 5.1:

(3) Total CH_4 generated = $\Sigma (W_{x,T,t,p} . Q_{x,T,t,p})$

Where

$W_{x,t,p}$ is the quantity of waste of type x landfilled in year t (dimensions mass) in pool p;

The Revised 1996 IPCC Guidelines (IPCC, 1997) define the Methane Correction Factor (MCF) as a multiplier on methane formation to reflect the fact that shallow or unmanaged disposal sites do not develop extensive anaerobic conditions typical of modern landfills and hence a proportion of waste decays aerobically and does not produce methane. For modern landfills, the MCF term is given the value of 1 (IPCC 1997 Table 6-2), but for unmanaged dumpsites a smaller figure may be used. As all solid waste disposal sites in the UK that have received biodegradable wastes since 1980 are believed to be typical of landfills rather than unmanaged dumpsites, the MCF for these sites has been assigned a value of 1. MCF has been assigned a value of 0.6 for old closed landfills that operated up to 1980 (IPCC 1997 Table 6-2).

The remaining term in equation 3 is F, the molar fraction of methane in landfill gas. This has been assigned the value of 0.5, the default value given in the Revised 1996 IPCC Guidelines.

The UK model for calculating landfill emissions has developed over the years to reflect the availability of better input data and improved modelling approaches. The AEA Technology model (Brown et al., 1999) of methane generation from landfill sites was used until 2002. This was updated and revised for Defra in 2003 by Land Quality Management (LQM) (LQM, 2003). Further revision of the LQM version of the model was made in 2005 by the consultants Golder Associates (Golder Associates, 2005) and the 2006 and 2007 NIR and CRF tables contains results from this model.

In 2008, a new model (MELMod) based on the previous methodology but with improved transparency, utility and ease of use and flexibility was developed by AEA (Brown et al., 2008). MELMod has been tested against the previous national assessment model and the two models yield identical results from the same input data. In addition to improving the structure and clarity of the national assessment model, AEA also identified a number of areas for improvement in terms of data quality and emission factors.

In 2010, the UK government commissioned further work to update the activity data (i.e. quantities of degradable organic carbon landfilled) and emission factors for landfill methane, building on recommendations made by AEA during their development of MELMod. This work, undertaken by Eunomia (Eunomia Consulting and Research, 2011) was peer reviewed

by independent experts from academia, industry, regulators and consultants in late 2010. Revisions to the MELMod input data and parameters that were approved by the peer reviewers were implemented for the calculation of the previous UK NIR (for 2009), submitted to UNFCCC in April 2011. The principal changes to the input data were summarised in the 2009 NIR. Further details on data sources and rationale are given in Eunomia's report.

Activity data for 2011 were taken from the following published data sources:

- England: "Local Authority Waste Management Statistics for England – Final Annual Results 2011/12," published by Defra (http://www.defra.gov.uk/statistics/environment/waste/wrfg23-wrmsannual/)
- Scotland: SEPA Waste Data Digest 12 (http://www.sepa.org.uk/waste/waste_data/waste_data_digest.aspx)
- Wales: StatsWales Official data on Wales (https://statswales.wales.gov.uk/Catalogue/Environment-and-Countryside/Waste-Management/Local-Authority-Municipal-Waste/Annual)
- Northern Ireland: Local Authority Collected Municipal Waste Data Reporting (http://www.doeni.gov.uk/waste_2011_appendix.xls)

8.2.2.1 Methane recovery from modern landfills

As outlined above, landfill operators are required under their permit conditions to control the release of landfill gas. For large landfills containing biodegradable wastes, this requires the use of impermeable liners and cover material, and the use of gas extraction systems. These typically consist of a system of gas wells (perforated pipes sunk into the waste) connected to a network of gas collection pipes. Suction is applied to the gas wells resulting in a slight negative pressure sufficient to draw out the landfill gas but not enough to draw excessive air into the waste. (Air ingress can result in aerobic decomposition of the waste, which produces considerable heat, and may lead to the waste catching fire, as well as shutting off methane formation). The landfill gas is fed into flares which oxidise the methane to carbon dioxide. The carbon dioxide so produced is not taken into further consideration for inventory purposes as it is considered to be entirely biogenic in origin. Many landfills that produce large quantities of methane recover the gas for power generation on a commercial basis.

A key factor in determining methane emissions is information on the amount of methane collected, either for utilisation or flaring. Data on utilisation is available and of good quality, but data on flaring is generally scarce and of poor quality. The current inventory is based on the estimates of gas collection efficiency developed by Golders (2005)[43] and described in further detail in their report and in subsequent inventory reports. The adopted recovery rates for modern landfills are estimated to have increased from 15% of the methane generated in 1990 to about 75% by 2005 and are assumed to have remained constant thereafter, with no gas collection for old pre-1980 closed sites

The continued use of the 75% time integrated collection efficiency for modern landfills was agreed with peer reviewers of the latest review of the assessment model input data undertaken by Eunomia. Further work has been commissioned to gain greater confidence in the amount of methane flared and this information will be taken into account when available for future inventory reports. Current estimates for methane recovered are given in **Annex Table A 3.7.1.2**.

[43] Golder Associates (2005), UK Landfill Methane Emissions: Evaluation and Appraisal of Waste Policies and Projections to 2050. Report version A.2, November 2005. Report for the UK Department of Environment, Food and Rural Affairs. Authors: Arnold, S. and Yang. Z. Report number 05529424.500

Regulatory guidance[44] for landfill operators bases permit conditions on a target to collect at least 85% of the methane formed in landfills receiving biodegradable waste. Non-achievement of this target, which applies to landfill cells and areas served by gas collection systems, may result in further inspections and permit conditions being imposed to improve collection rates. There is high uncertainty in the proportion of gas collected, as noted in the main report. Large-scale passive venting of landfill gas is no longer accepted under permitting conditions and impermeable barriers are required as best practice to prevent the migration of landfill gas off-site.

8.2.2.2 Gas Utilisation

Power generation is currently the dominant use for landfill gas in the UK and good data are available on this from official sources. Power generation from landfill gas has benefitted considerably from government support schemes to encourage the uptake of renewable forms of energy and landfill gas to electricity has been one of the most successful technologies to have benefitted. The first of these schemes, the Non-Fossil Fuel Obligation (NFFO), began in 1990 in England and Wales, with variants in Scotland and Northern Ireland. Although schemes supported under NFFO continue to operate, the system was replaced in 2002 by the Renewables Obligation, which is the main support scheme for renewables in the UK. The essence of these support mechanisms is to provide an obligation on electricity suppliers to meet an increasing proportion of their needs from renewable sources, and in addition to provide market security for electricity from renewable sources, in order to stimulate investment in these technologies. Details of the schemes are available from Ofgem.[45]. To receive support under these schemes, electricity suppliers must inform the authorities of the amount of electricity from renewable sources they have supplied, and consequently there is a high level of confidence in the quality of the official figures. From knowing the typical conversion efficiency of landfill gas electricity generation and the calorific value of methane it is simple to calculate the quantity of methane used for power generation.

The most widely deployed technology for power generation from landfill gas is the use of reciprocating internal combustion engines as the prime mover, powering a conventional alternator to generate the electricity. These are mainly based on the spark-ignition principle, using multi-cylinder engines based on designs developed for heavy duty road transport. Compression-ignition engines using diesel oil as a pilot fuel have also been used in the UK, as have other prime movers such as gas and steam turbines.

Other uses for landfill gas have been demonstrated, both in the UK and elsewhere, such as its use as a direct fuel in industrial processes such as brick and paper making, but these applications depend on having a fuel user close to the landfill. In addition, support for power generation applications has made this option more commercially attractive than direct use, and a number of direct use schemes in operation in the 1980s subsequently converted to power-only with the introduction of the support schemes for electricity.

There is increasing interest in removing contaminants from landfill gas and using the methane as a fuel for vehicles or for direct injection into the gas distribution system. Examples of both these applications are seen in other European countries. However, it is understood that there is currently only one example in the UK (the use of liquefied methane from landfill gas to fuel refuse collection vehicles). The scheme, which started in 2008, is

[44] See “Guidance on the management of landfill gas” Landfill Technical Guidance Note TGN(03) The Environment Agency and Scottish Environment Protection Agency 2004.

[45] Ofgem (Office for Gas and Electricity Markets) . http://www.ofgem.gov.uk/Sustainability/Environment/Pages/Environment.aspx

claimed to use the equivalent of about 5 Gg of landfill methane per year[46], although this does not appear to be included in the current issue of DUKES.

Current data on the amount of methane used for power generation, calculated from the electricity generated from landfill gas as reported in the Digest of UK Energy Statistics (DUKES, 2012), is given in **Annex Table A 3.7.1.2**.

8.2.2.3 Flaring

Until recently, information on the volume of landfill gas treated by flaring was not collected by the environmental regulators and was therefore not publicly available. Instead, estimates of methane capture were based on energy recovery statistics and information on flare capacity, rather than on actual volumes of gas treated in this way. Information on flaring capacity was obtained through consultation with flare manufacturers. LQM (2003) collected information from all but one of the UK flare companies contacted. The data collected was divided into flares supplied for routine flaring and flares supplied as back-up to generation sets. The data produced demonstrates total flare capacity as opposed to the actual volumes of gas being flared in each year. There are difficulties in ascertaining the actual volumes of LFG burnt, as detailed records, if they exist at all, are held by individual site operators. The methodology was used to derive the estimated gas collection efficiency for modern landfills (75%) noted above.

The efficiency of flares in destroying methane has improved substantially since 1990. Modern shrouded flares now required by the regulators typically remove at least 98% of incoming methane, compared with the now obsolete candle flares common in the 1980's that released about 10-15% of unburnt methane in the combustion off-gas[47].

Further work is on-going to improve estimates of landfill gas flare utilisation as they currently contain a high level of uncertainty. The estimates shown in **Table A 3.7.1.2** are based on the estimate of methane collected, less the amount used for power generation. The amount flared also includes a minor proportion used for non-electricity generation proposes such as direct use and as a vehicle fuel, mentioned above.

Much better quality data on the amounts of landfill gas flared is now becoming available from the UK's environmental regulators. Operators of landfills that are permitted under the Landfill Directive now have to report the volumes of landfill gas flared, as well as that used in engines and for other purposes. Whilst this new data is still undergoing quality checks, initial assessment suggests that the calculations based on the 2003 study may have over-estimated the quantity of methane flared. We expect to include new estimates of flaring based on reported flaring volumes in next year's NIR and to update the collection efficiency accordingly.

8.2.2.4 Overseas Territories and Crown Dependencies

Data on the annual tonnage of MSW landfilled has been obtained from some, but not all, territories. Where possible these have been used and then historic UK emission estimates used where this has not been possible in order to calculate a consistent time series. A number of territories were assumed to have no emissions arising from this sector: Bermuda (ceased in 1995), Jersey, Falkland Islands and the Isle of Man (ceased in 2004).

[46] SITA 2008 Powered by waste – creating fuel from landfill gas. http://www.sita.co.uk/downloads/Gasrec-web.pdf

[47] "Guidance on landfill gas flaring" Environment Agency and Scottish Environment Protection Agency 2002.

8.2.3 Uncertainties and time-series consistency

The Tier 1 uncertainty analysis in **Annex 7**, shown in **Table A7.6.1** to **Table A7.6.5**, provides estimates of uncertainty according to IPCC source category and gas. There are many uncertainties in estimating methane emissions from landfill sites. The model is particularly sensitive to the values assumed for the degradable organic carbon (DOC) present in different fractions of waste, and the amount of this that is dissimilable (i.e. is converted to methane and carbon dioxide), as well as to the oxidation factor. These parameters are poorly understood, and field and experimental observations exhibit wide variation, so uncertainties are inevitably high, and the uncertainty estimates in **Annex 7** are intended to reflect this as well as uncertainties in the other data and model parameters.

The estimates for all years have been calculated from the MELmod model and thus the methodology is consistent throughout the time series. Estimates of waste composition and quantities have been taken from different sources – prior to 1995 they are from Brown *et al.* (1999), prior to 2000 they are based on the LQM (2003) study and from 1995 they are based on new information compiled by Eunomia (Eunomia, 2011). The new waste to landfill data indicates a significant decrease in the amount of LA-controlled and C&I waste sent to landfill since about 2002 and 2003. Similarly, the approach to calculating DDOC, the main driver behind methane formation, has been reviewed and updated in the light of experimental and field measurements and, where endorsed by peer reviewers, the new data have been incorporated into MELMod. Further details are given in **Appendix 3**.

Uncertainty in collection efficiency is believed to be a major source of uncertainty in overall emission of landfill methane. Landfill permit conditions require operators to aim for 85% collection efficiency for cells or areas served by gas collection systems and requirements to design and operate landfills to minimise gas escape have strengthened considerably since the 1990s. Reliable data on methane collected for power generation are available (which set a lower limit on the actual gas collection) but better data on landfill gas flaring is needed to determine overall amounts of methane collected. Overall, it is believed that a 75% collection efficiency for methane as an average over the gas-producing life of modern landfills is feasible, given industry and regulator experience, but further measurements are being pursued to improve confidence in this key factor.

Oxidation of methane in the surface layers of landfills is a further source of uncertainty in overall emissions, but as this only affects methane that is not extracted by a landfill gas collection system, its impact on sites with extensive gas collection is obviously less than in sites lacking active gas collection. According to current estimates, about 69% of methane generated in all UK landfills is recovered – i.e. including old sites without gas collection. The remaining methane is available for oxidation and, in the absence of better data, the IPCC oxidation default factor of 10% is applied to this remainder. There is, however, reason to believe that this may be highly pessimistic, since oxidation rates of 30-90% and higher have widely reported in the literature, and hence emission levels may be over-stated. A particular challenge in deciding on oxidation rates for use in a national landfill model is the high level of variability in field measurements, reflecting a wide range of factors such as nature and porosity of the surface layers, moisture content and temperature, along with methane production rates in the underlying waste.

Some confidence in the current estimate of methane emissions based on the revised national model can be drawn from comparison with the results of a preliminary study that used statistical stratification of landfills, along with site-specific modelling of gas formation (using the Environment Agency's GasSim 2 model), to determine the types of landfill that

contribute most to methane emissions. The work was undertaken by Jacobs Engineering (Jacobs Engineering UK Ltd, 2010) for the Environment Agency.

The study estimated total emissions of methane from landfills in England and Wales in 2007 at 732 ± 253 Gg (± 95% confidence interval). To compare this estimate with the current national (UK) estimate, we need to scale up the Jacobs results for England and Wales. This can be done on the basis of relative population. Assuming the population of England and Wales to be 89% of that of the UK (ONS, 2010), the corresponding emissions would be 831±287 Gg methane for the UK. This compares well with the estimate of UK methane emissions for 2007 of 778 Gg methane.

8.2.4 Source-specific QA/QC and verification

The verification of MELMod has been described in the 2008 NIR. The updating undertaken by Eunomia (Eunomia, 2011) in 2010 has resulted in updating of input data to the model only, with no changes implemented as to calculation methodology other than where indicated, so no revision of the 2008 NIR is required in this respect.

The changes to the model input data recommended by Eunomia were peer reviewed by independent experts from academia, industry, regulators and consultants in late 2010, before their incorporation into the UK inventory. The implementation of the recommended changes within the model has now also been reviewed, and the changes arising from this review were set out in the previous NIR.

8.2.5 Source-specific recalculations

No recalculations have been made to this category.

8.2.6 Source-specific planned improvements

Emission factors, model parameters, and activity data will be kept under review. Defra and the environmental regulatory agencies in the UK have carried out a small pilot study, with a view to undertaking a wider study to measure methane emissions from a selection of landfills of different ages and regulatory control regimes whilst simultaneously measuring surface soil methane oxidation rates. This research will be used with estimates of methane flared at landfills to revise the calculations of methane capture rates and hence provide better evidence to support reworked estimates of landfilled waste emissions in the UK. Depending on the results of the pilot study, and any further research in this area, it is possible that MELMod may be further updated in the 2014 NIR.

8.3 SOURCE CATEGORY 6B – WASTEWATER HANDLING

8.3.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	6B1: Industrial Waste Water Treatment 6B2: Sewage Sludge Disposal (CH_4) 6B2: Sewage Sludge Disposal (N_2O)	T1 CS, OTH T1	D CS, OTH D
Gases Reported	CH_4, N_2O		
Key Categories (Trends)	Wastewater Handling – N_2O		
Key Categories (Level)	Wastewater Handling – N_2O		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Emissions for 6B are included as a separate category within 6B.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Improved completeness through inclusion of new estimates for emissions from industrial waste water treatment.		

Emissions reported in 6B1a arise from wastewater handling in a number of industry sectors in the UK where organic content of effluent is high. No data are currently available on sludge removal so all water treatment, sludge treatment and disposal emissions are reported aggregated under 6B1a.

Emissions reported in 6B2b arise from wastewater handling, sludge treatment and disposal in the UK's municipal waste water treatment system which encompasses the treatment of effluent and sludge from residential and commercial sectors as well as trade waste from many industrial sites in the UK.

Methane is released from handling of wastewater and its residual solid by-products (i.e. sludge) under anaerobic conditions, due to the decomposition of organic matter by bacteria. Nitrous oxide is released from human sewage during waste water handling due to the release of nitrogenous material from proteins.

8.3.2 Methodological Issues

The emissions from 6B1 and 6B2 are estimated for the following sources in the UK:

- ***6B1 Industrial Waste Water Treatment (CH_4).*** Default IPCC methodology applied to UK waste water estimates of organic load from the food and drink and chemical industries.
- ***6B2 Domestic and Commercial Waste Water (CH_4).*** UK-specific method, using activity data for the municipal waste water treatment volumes, organic content and sludge treatment and disposal routes. Emission factors are derived from water company reported data for recent years, extrapolated back to 1990.

- ***6B2 Domestic and Commercial Waste Water (N_2O).*** Default IPCC methodology applied to UK time series of population and protein intake estimates from food surveys.
- ***6B3 OT and CD Sewage Treatment (All).*** For the majority of overseas territories and crown dependencies, wastewater emissions are estimated using UK data and scaled by population. Emissions from Montserrat were estimated for the first time using IPCC Tier 1 methodology based on population data. Data specific to Bermuda were provided by the territory and used within the time series, interpolating and extrapolating where necessary.

6B1 Industrial Waste Water Treatment

In the UK, a high proportion of industry trade waste water is disposed to the municipal sewer system and treated by water companies together with the sewage and effluent from domestic and commercial sectors. In the data reported by the water companies and used to generate methane emission estimates in 6B2 (see below), the annual reporting to water regulators includes explicit data on the BOD from "trade waste" and the total BOD treated (i.e. including domestic and commercial effluent) in the municipal systems. The share of total BOD that is attributable to the industry sector (i.e. "trade waste", managed via contracts between water companies and industry operators) is variable across the UK and across years. In 2008 (before the economic down-turn) the trade waste share of total BOD treated in the municipal waste water systems (i.e. emissions from which are reported in 6B2) was 13.2%, but from 2009-2011 the figure has been in the range 10.8-11.1%.

In addition to the emissions reported in 6B2 due to trade waste disposed to municipal sewers, where large industrial sites that have on-site waste water treatment plant are regulated under IPPC/EPR, then the annual IPPC/EPR reporting to regulator inventories (PI/SPRI/ISR) includes the requirement to report any methane emissions from the waste water effluent plant. The PI/SPRI/ISR data on methane emissions are used within the UK GHGI, and included within many IPCC source categories, but the lack of source-specific detail in the PI/SPRI/ISR reporting does not enable the waste water treatment emission estimates from these industrial facilities to be split out and reported separately in the CRF.

In practice it is not straightforward to ascertain the extent to which emissions from waste water treatment are consistently included in operator estimates across different industry sectors, as the IPPC/EPR data are not presented "by source", but rather "by installation". Within sector-specific guidance to plant operators on pollution inventory data preparation, emissions of methane from wastewater treatment are not highlighted as a common source to be considered, whilst in guidance for several industrial sectors, wastewater treatment is singled out as a potentially significant source of ammonia and nitrous oxide emissions.

Therefore, some industrial waste water treatment methane emissions are already reported within a range of IPCC source categories, due to the lack of transparency of available source data from UK environmental regulatory reporting systems.

At the 2012 in-country review, the lack of transparency and level of emissions reported in 6B2 led the expert review team to recommend that the UK introduces new separate estimates of emissions of methane from industrial waste water treatment. Therefore in the 2013 submission the inventory agency has added new time series estimates using the IPCC default methodology and available UK activity data from high-BOD-emitting UK industry sources, primarily in the food and drink and chemical production sectors. The UK inventory agency considers that this introduces a double count to the inventory, but is a conservative estimate to ensure completeness of the inventory.

Summary of Estimation method for New UK 6B1 Estimates
In developing new industrial waste water methane emission estimates, the following UK industries have been considered, as they are high-BOD-emitting waste water source sectors in the UK economy:

- Organic Chemicals
- Food and Drink, including:
  - milk-processing
  - manufacture of fruit and vegetable products
  - potato processing
  - meat processing
  - production of alcohol and alcoholic beverages
  - breweries
  - manufacture of animal feed from plant products
  - malt houses
  - fish processing

The estimation methodology is based on the following data and assumptions:

- Default values for Chemical Oxygen Demand (COD) and amount of wastewater generated used for organic chemical production from the IPCC 2000 GPG;
- PRODCOM data (supplied by the Office of National Statistics) used for organic chemical production (2009) and scaled using Office of National Statistics Index of Production (IOP) for other years (1997 is earliest year for IOP so 1990-1996 estimates use the 1997 value).
- Total organic load obtained for food and drink industry sub-sectors in a 2002 paper by Defra48, scaled across the time series using Office of National Statistics Index of Production data (as above, 1997 data are used for 1990-1996 also).

[The UK activity data are summarised for selected years across the time series in Annex 3, ***Section A3.8.2****]*

The inventory agency considers that these new emission estimates are very conservative, and likely to be over-estimates, noting that:

- There is no information currently available on how much wastewater for the chemical and food and drinks industries are treated on site and how much is included in emissions of wastewater sent to sewers. We have therefore used IPCC default values for the amount of wastewater consumed per tonne of output and amount of COD in the wastewater, and assumed all wastewater is treated on site rather than any of it disposed to municipal sewers.
- There is no information currently available on how much sewage sludge is removed and sent to landfill or applied to agricultural land. Although it is likely that this activity does take place, due to the absence of information, the default value of zero has been used.
- There is no information on the amount of methane recovered, so the default value of zero has been used, although it is likely that this activity also takes place. There is some evidence from the EU ETS dataset that several UK food and industry facilities collect methane from anaerobic digestion systems and use the gas a fuel source.

[48] http://www.defra.gov.uk/publications/files/pb6655-uk-sewage-treatment-020424.pdf

- There is no UK specific information on the split of aerobic and anaerobic industrial wastewater treatment and therefore the IPCC default estimate has been used. It is likely that aerobic treatment systems will be used in many UK facilities.

6B2 Domestic and Commercial Waste Water (N_2O)

The UK estimates for methane from domestic and commercial waste water and sewage sludge treatment and disposal are derived from a time series of activity data for (i) total mass of sewage sludge disposed, and (ii) population equivalent of effluent treated in the municipal water treatment systems. These data cover all of the UK water company activity since 1990, and reflect the shifts in UK water sector regulation and management, dominated by a step-change in activity due to the impact the Urban Waste Water Treatment Directive which banned dumping of sewage sludge to sea; this activity ceased in the UK in 2000, and the activity data exhibit an increase in sewage sludge treatment and disposal by other methods between 2000-2001 as the UK industry responded to the new regulations. UK water companies provide emissions data and activity data on amount of sludge disposed, however the available information on the split of emissions and treatment between sludge and wastewater are inconsistent across the time series. For example, there are no data on population equivalents of waste water treated prior to 2002 and hence the estimates for digestion are uncertain from 1990-2001. As a result, all CH_4 emissions for 6.B.2.1-Domestic and Commercial Wastewater are currently reported in the UK inventory under 6B2b Sludge.

Waste Water Treatment and Sludge Disposal Activity Data

The availability of activity data is variable across the time series. Activity data are available at a more aggregated level (across countries: England and Wales, Scotland, Northern Ireland, and with less detail on sludge fate) for the early part of the time series within EPSIM data published by UK Government (Defra, 2004). More detailed activity data (from each of 12 UK water companies, with details on sludge treatment and fate) are available for recent years.

In recent years, each of the UK's 12 water and sewerage companies report annual activity data on water treatment, sewage sludge arisings and the ultimate fate of sewage sludge, to UK industry regulators. The activity data reported by each company includes data that are used to estimate company GHG emissions:

- Total volume of sludge disposed (kt dry solids)
- Trade effluent load (BOD/yr)
- Total annual load (BOD/yr)
- Population Equivalent Served ('000)

In addition, each company provides a detailed split of sewage sludge disposal routes, including data (kt dry solids per year) for the following activities:

- Incineration
- Composted
- Landfill
- Land reclamation
- Farmland
- Disposal at sea (up to the year 2000, when this activity was banned)
- Other

From 1997 to 2008, each of the 10 water companies in **England and Wales** reported sludge disposal activity to the industry regulator, OFWAT, broken down across 8 sludge disposal

routes: incineration, composting, landfill, land reclamation, farmland untreated, farmland conventional, farmland advanced and other. Since 2009 the data published for each water company is limited to the total activity for all sludge treated and disposed, with no detailed breakdown of ultimate disposal fate; for each water company in England and Wales, therefore, the 2008 breakdown across the 8 disposal routes has been used to estimate the detailed activity from 2009 onwards.

For years prior to 1997, the EPSIM data present a breakdown of sewage sludge disposal data across 5 options: farmland, incineration, landfill, sea disposal and other. No additional information is available, such as the BOD loading of the municipal sewerage system, nor the population equivalents treated by UK water companies.

In **Scotland** the same level of detailed activity data as outlined above for companies in England and Wales have been available since 2002 and continue to be published to 2011, from the Water Commissioner for Scotland; EPSIM data are used for 1990-2001.

In **Northern Ireland**, fully disaggregated data are only available from the water regulator, UREGNI, since 2007; the Defra EPSIM statistics are used to provide activity data for the early part of the time series to 2003, whilst the Northern Ireland activity data published by the regulator for 2007 are extrapolated back to 2004. EPSIM data are used for 1990-2003.

Emission Estimation: Use of UK-specific Factors

The UK GHG inventory estimation method follows a UK water industry GHG emission estimation methodology developed by UK Water Industry Research (UKWIR) and used by all UK water companies to generate their annual emission estimates from all sources / activities:

- Methane emission estimates from sludge **digestion** are calculated using the activity estimates for Population Equivalents. *Activity data prior to 2002 are not available, and therefore the 2002 data are used for all years from 1990-2001*;
- Methane emission estimates from **water and sludge treatment** use the activity data for total mass of sewage sludge arisings in the year, *which are available for all years*;
- Residual methane releases from secondary treatment and disposal options use the mass for sludge disposed to those routes, for: **farmland / land reclamation**, **composting**. *Activity data for composting is reported as zero from all companies in England and Wales over 1997-1999, and there are no activity data for earlier years; hence composting activity is assumed to be zero from 1990-1999 inclusive*. *Activity data for sludge disposed to farmland / land reclamation are available for all years until 2008; estimates for 2009-11 are estimated based on the share of total sludge disposed to agriculture in 2008.*

Methane emissions from sewage sludge disposed to landfill and incineration are accounted for in 6A and 6C, and hence no estimates are included in 6B2 to avoid a double-count. No estimates are made for sewage sludge disposed to sea or to “other” disposal routes; in the 10 years since disposal to sea has ceased, the disposal to “other” sources has averaged 4.0% of total sludge disposals, with known fates to forestry and used for topsoil. Whilst the initial methane emissions from water and sludge treatment (to generate this mass of sludge then disposed to “other”) are included in the UK GHGI, there are no emissions data pertaining to the disposal to “other” sources from the UK water companies and hence it is assumed that there are no additional methane emissions from these disposal routes..

UK-specific emission factors are applied to the activities outlined above. These factors are derived from UK water industry emissions data reported to the inventory agency, through use

of the UKWIR estimation spreadsheet tool that all UK water companies utilise. The UKWIR tool provides emission factors for sub-processes within the industry, enabling water companies to calculate their methane emissions based on their stock of water treatment equipment and effluent inputs to individual water treatment works. From the aggregated industry reported emissions and activity data, implied emission factors for digestion, water and sludge treatment, composting and disposal to farmland are derived and applied across the time series.

Water company reporting of emissions to the inventory agency is not comprehensive; emissions data are only available from 2009 onwards, and only from up to 7 of the 12 UK water companies in any one year. The inventory agency note that there is a limited dataset from which to derive UK-specific emission factors, despite extensive stakeholder consultation with industry contacts in recent years. However, there is good consistency across the emission factors derived from the different water companies and the data are based on UK-specific water treatment facilities, effluent inputs and treatment / disposal activities, and therefore are regarded as the best available data upon which to derive inventory estimates.

For further details of emission factors see **Annex 3, section A3.8.3.**

Reporting of Methane Recovery from Sewage Treatment

The inventory compilation method uses industry-wide data on emissions and calculations are not conducted at a technology level; no specific consideration of the use of anaerobic digestion or use of sewage gas in power generation is included in the estimation method and these factors do not affect the veracity of the emission estimation method. To derive the estimates of methane recovery from sewage treatment that are reported within the CRF Table 6.Bs1, the inventory agency uses national statistics on electricity generated through sewage sludge digestion and back-calculates an estimate of methane recovered.

Data on the annual amount of electricity generated using sewage gas are provided in DUKES (DECC, 2012), and consultation with the energy statistics team has clarified that they assume a 35% energy efficiency factor for these systems. The inventory agency therefore uses the 35% conversion assumption to back-calculate the national annual sewage gas energy input to these power plant, and then uses the sewage gas calorific value (published in DUKES, DECC 2012) to derive the mass of methane recovered to report in the CRF. The emission calculation is not affected by these assumptions.

8.3.2.1 6B2 Domestic and Commercial Waste Water (N_2O)

Nitrous oxide emissions from the treatment of human sewage are based on the IPCC (1997) default methodology. The most recent average protein consumption per person is based on the Expenditure and Food Survey (Defra, 2011); see **Table 8-1**. For the purposes of the 2011 estimates within the inventory, the Expenditure and Food Survey 2012 was not available in time, and therefore the data for 2010 has been used as a best estimate.

In previous years, the protein consumptions used to estimate emissions were “household intakes”. However, Defra now produce a time series of the estimates of the small amount of additional protein from consuming meals eaten outside the home; this intake is called “eating out intakes”. This time series is only available from 2000 onwards. For values between 1990 and 2000 an average of the data available is applied. The sum of the “household intakes” and “eating out intakes” then provides the total protein consumption per year per person.

Table 8-1 Per capita protein consumption in the UK (kg/person/yr), 1990-2011

Year	Protein consumption (kg/person/yr)
1990	27.9
1991	27.6
1992	28.4
1993	28.2
1994	28.3
1995	28.6
1996	29.4
1997	29.3
1998	29.1
1999	28.7
2000	29.9
2001	30.0
2002	30.0
2003	29.7
2004	29.5
2005	29.8
2006	29.7
2007	29.3
2008	28.5
2009	28.7
2010	28.7
2011*	28.7

*2010 data used, as 2011 data not published in time for inventory compilation.

The nitrous oxide emissions are calculated by multiplying the total protein consumption per year per person by the fraction of nitrogen in protein (0.16 kg N/kg protein based on the IPCC rev 1996 Guidelines) by the emission factor (0.01 kg sewage-N produced based on the IPCC rev 1996 Guidelines).

This derives a total for the UK nitrous oxide emissions from sewage sludge, but not all of those emissions are allocated to 6B2. The nitrous oxide emissions from sludge spread on agricultural land are reported under IPCC source category 4D Agricultural Soils, and therefore to avoid a double-count the emissions reported in 6B2 are the difference between the UK total from the IPCC default method, and the estimate included in 4D. **Table 8-2** below summarises the data reported in the CRF, across 4D and 6B, as well as the time series of estimates of emissions from waste water treatment and sewage sludge treatment and disposal in the Overseas Territories and Crown Dependencies.

Allocation of 6B2 Nitrous Oxide Emissions across Waste and Agriculture

Nitrous oxide from water treatment and sewage sludge disposal is mainly reported in 6B2, but a component of these emissions is reported under 4D Agricultural soils, as emissions from sewage sludge disposed to agricultural land are accounted for within the overall estimates of nitrogenous inputs to UK soils that lead to nitrous oxide emissions.

Therefore, in order to avoid a double-count in the UK GHG inventory, the data reported in 6B2 excludes that component of emissions from sludge disposed to agricultural land.

Note that no amendment is made to account for the nitrous oxide that is reported in 6C from sewage sludge incineration, as it is not explicit that the nitrogen emitted in N_2O from incineration is derived from the sewage sludge incinerator feedstock rather than from the combustion air. There may, however, be a very small double-count of nitrous oxide emissions as a result of this approach.

To aid transparency of the time series of nitrous oxide emissions in 6B, including the emissions allocated to 4D, see the table below. This also includes the estimates for emissions in Overseas Territories and Crown Dependencies, which are reported in the CRF under 6B3 Other, and include estimates for: Bermuda, Cayman Islands, Guernsey, Isle of Man, Jersey and Montserrat.

Table 8-2 Nitrous Oxide Emissions in the UK Inventory: Allocation to Waste and Agriculture Source Categories, 1990-2011

CRF	Source	Units	1990	1995	2000	2005	2010	2011
n/a	Total UK emissions using IPCC method (Excluding OTs and CDs)	kt N_2O	4.02	4.16	4.41	4.52	4.49	4.52
4D	Direct soil N_2O emissions from sewage sludge	kt N_2O	0.28	0.31	0.33	0.71	0.61	0.66
6B2	Reported UK waste water sector N_2O emissions	kt N_2O	3.74	3.85	4.09	3.80	3.88	3.86
6B3	Waste Water N_2O emissions, OTs and CDs	kt N_2O	0.05	0.05	0.05	0.06	0.06	0.06

Use of UK-Specific Protein Consumption Data instead of FAO Data

The FAO estimate of per capita protein consumption is based on supply balance sheets for all commodity items. For each commodity supply balance sheet, factors are applied to the estimate of supply for human consumption to derive total protein consumption and a per capita figure is obtained by dividing by population statistics. These are summed across the supply balance sheets to derive a total protein consumption estimate for a country.

The FAO estimate is therefore an aggregate calculation based on aggregate commodity supply data. It uses common conversion factors (not specific to any country) to derive food, protein and fat per capita consumption estimates. It also relates to quantities available for consumption and will not be net of any losses (including e.g. fat trimmed from meat) beyond the farm-gate through to retail. These methodological limitations of the FAO estimates are more significant for developed countries such as the UK where a greater proportion of consumption is in the form of processed products.

The UK GHGI estimate of protein consumption is derived from the Expenditure and Food Survey (Defra, 2011). This is a sample household survey in which households record the actual purchases of food they make. UK-specific conversion factors are then applied to these individual food items to estimate consumption of protein and other nutrients. The UK-specific conversion factors are based on a detailed analysis of the individual types of food purchased and contrasts to the more broad-brush factors used by the FAO. The Expenditure and Food Survey estimate is also net of any losses through the food chain through to retail as it is based on actual purchases. The only limitation to the Expenditure and Food Survey is that it may have an element of under-recording due to purchases of some food items not being included in the diary of survey participants, but the inventory agency considers that it is more representative of UK protein consumption per capita than the FAO estimate.

8.3.3 Uncertainties and Time-Series Consistency

As outlined in **Section 8.3.2**, the method for deriving methane emission estimates for 6B2 uses activity data from across the time series, and applies emission factors that are derived from reported emissions data from 2009 onwards from up to 7 out of 12 UK water companies. These emission factors are then applied to the activity data across the full time series. The emission estimates included in this submission are uncertain due to the limited coverage of the source data used to derive the industry emission factors.

Furthermore, the limited activity data time series for 6B2 due to changes in data reporting across the time series limits the accuracy of the estimates for the early part of the time series; for example, no comprehensive UK data for Population Equivalents (PE) of waste water treatment are available prior to 2002, and hence the estimates of methane emissions from digestion for 1990-2001 are somewhat uncertain, as they are based on the 2002 activity data. Note, however, that the aggregate UK PE data is in the range 73,000 ± 200 during 2002-2006, and therefore the variability in the data are quite low; furthermore, the use of data on digestion activity from after the ban on disposal of sewage to sea (in 2000) is very likely to introduce a slightly conservative estimate for those earlier years in the time series, rather than an under-report.

In previous reviews of the UK inventory, the UNFCCC ERT has questioned the accuracy of the source estimates due to uncertainty regarding the applicability of factors derived from one year and from only a sub-set of the UK water industry and then applied to water industry operations throughout the time series. The inventory agency acknowledges that the estimates are somewhat uncertain and that further work is needed to consult across the industry to seek to improve the method. However, we remain confident that the method is an improvement compared to the previous approach which used data from a 1996 study, based on information from the early 1990s and then extrapolated the emission estimates forward based on population trends. The current method, uses a published national set of activity statistics that reflect the changing fate of sewage sludge treatment and disposal. In the UK the water industry has undergone a marked shift in treatment and disposal practices since the Urban Waste Water Treatment Directive of 1999 banned the dumping of sewage to sea. The inventory method for methane uses data from UK companies based on recent research specific to the estimation of non-CO_2 gases from waste water treatment works, and applies the factors to time series of national activity data. See **Annex A3.8.3** for further method details, and **Section 8.3.6** below for an insight into the planned improvements for this source method.

8.3.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

8.3.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 8-3** and emission factors in **Table 8-4** below. For information on the magnitude of recalculations to Source Category 6B, see **Section 10**.

6B2 CH_4 estimates

Since the previous submission, the stakeholder consultation with water company carbon managers has led to provision of more GHG emissions data; the new data has increased the

UK methane emission factors from water treatment and sewage sludge disposal to land, for: digestion, disposal to agricultural land.

As a result of these revised factors, inventory recalculations in most years have increased emission estimates by around 4%, with bigger increases in the early part of time series (e.g. 8% increase in 1990), due to the year-specific mix of disposal activities and especially the increase in methane emission factor for sludge disposed to agricultural land.

Waste water treatment estimates for Montserrat have also been included for the 2013 submission.

Table 8-3 6B Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
6B1	Industrial Waste Water Treatment	Non-fuel combustion			1.376	1.269	kt COD	New source following UNFCCC review

Table 8-4 6B Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
6B1	Industrial Waste Water Treatment	CH4	Non-fuel combustion			0.175	0.175	kt / kt COD	New source following UNFCCC review
6B2	Sewage sludge decomposition	CH4	Non-fuel domestic	0.232	0.258	0.250	0.264	kt / million people	New data from water companies led to derivation of a higher IEF for sludge disposal to agricultural land and in digestion. This led to increases in emission estimates of between 4-8% across the time series, depending on the year-specific mix of sewage sludge treatment and disposal fates.
6B2	Sewage sludge decomposition	N2O	Non-fuel domestic	0.065	0.059	0.065	0.062	kt / million people	Revised data for 2010 protein consumption in the UK.

8.3.6 Source Specific Planned improvements

Consultation with water industry contacts and regulators will be progressed within 2013, to:

i) Further engage with water companies to seek more complete reporting of emissions data and activity data, building on the example of the 7 out of 12 companies that have reported emissions data to date;
ii) Seek industry advice on how to improve the emission estimates from earlier in the time series, reviewing the current approach of back-extrapolation of emission factors from more recent research which introduces additional uncertainty;
iii) Review data available from environmental regulators pertaining to industrial waste water treatment emissions, volumes, characteristics (e.g. organic load).

No new data has been provided to date, but the Environment Agency, OFWAT and all UK water companies have been contacted to request additional data to improve the current approach and reduce uncertainties in the UK inventory estimates, seeking to ensure that the estimates presented in the inventory are representative of the industry across the UK. The investment of time and resources into taking these improvement actions forward will be determined by the NISC, taken in context of the available inventory research budget and the level of priority assigned to these estimates, accounting for their significance in the UK GHGI emission totals.

The inventory agency will review available data on disposals of sewage sludge to "other" (i.e. non-specified) disposal routes and consider options for deriving methane estimates for this activity.

8.4 SOURCE CATEGORY 6C – WASTE INCINERATION

8.4.1 Source Category Description

Emissions sources	Sources included	Method	Emission Factors
	6C: Incineration: MSW Incineration: Sewage Sludge Incineration: Clinical Incineration: Chemical Accidental fires - vehicles	T2 T2 T2 T2 T2	CS, D CR, D CS, CR, D CS, D CS
Gases Reported	CO_2, CH_4, N_2O, NO_x, CO, NMVOC, SO_2		
Key Categories (Trends)	None identified		
Key Categories (Level)	None identified		
Key Categories (Qualitative)	None identified		
Overseas Territories and Crown Dependencies Reporting	Included in the CRF with the UK MSW incineration, since the same emission factors are applied.		
Completeness	No known omissions. A general assessment of completeness for the inventory is included in Annex 5		
Major improvements since last submission	Inclusion of N_2O to chemical waste incineration in response to UNFCCC review.		

This source category covers the incineration of wastes, excluding waste-to-energy facilities. In the UK, all MSW incineration plant have recovered energy since 1997, and so emissions are reported under CRF source category 1A1a. For the years 1990-1996, at least some MSW was incinerated at plant with no energy recovery, so emissions are split between 1A1a and 6C for those years, in proportion to the waste burnt with and without energy recovery respectively. All incineration of chemical wastes, clinical wastes, sewage sludge and animal carcasses is reported under 6C. In-situ burning of agricultural waste e.g. crop residue burning is reported under category 4F.

There are approximately 70 plant incinerating chemical or clinical waste or sewage sludge and approximately 2600 animal carcass incinerators (estimated in AEA Technology, 2002). Animal carcass incinerators are typically much smaller than the incinerators used to burn other forms of waste.

This source category also includes emissions from crematoria.

Emissions of CO_2 and N_2O from accidental vehicle fires are not estimated as there are no suitable emission factors available.

8.4.2 Methodological Issues

Emissions of CO_2, CO, NO_x, SO_2, and VOC from chemical waste incinerators are estimated based on analysis of data reported to the Pollution Inventory (Environment Agency, 2012). This only covers England and Wales, but there are not thought to be any plants in Scotland and Northern Ireland. Emissions data are not available for all pollutants for all sites and so some extrapolation of data from reporting sites to non-reporting sites has been done, using estimates of waste burnt at each site as a basis. The gaps in reported data are usually for smaller plants but the need for extrapolation of data may contribute to significant variations in the quality of the estimates. The emissions of N_2O from chemical waste incinerators are the default factor given in the IPCC guidelines (2006).

Emissions of CH_4, CO, N_2O, NO_x, SO_2 and VOC from sewage sludge incinerators are estimated from a combination of data reported to the Environment Agency's Pollution Inventory, supplemented with the use of literature-based emission factors for those pollutants where the Pollution Inventory does not give information sufficient to derive estimates. Emissions of NO_x are estimated using Pollution Inventory data while emissions of all other direct and indirect greenhouse gases are estimated from literature-based emission factors. The factor for N_2O is the default factor given in the IPCC good practice guidance for UK sewage sludge incineration. Emission factors for other pollutants are taken from the EMEP/CORINAIR Emission Inventory Guidebook. The quantity of waste burnt annually is estimated, these estimates being based on estimates for individual years, given in the literature.

Emissions of CO_2, CH_4, CO, N_2O, NO_x, SO_2, and VOC from clinical waste incinerators are estimated using literature-based emission factors. The factor for CO_2 is the default factor given in the IPCC good practice guidance, while the factor for N_2O is the default for UK MSW incineration given in the same source. Emission factors for other pollutants are largely taken from the EMEP/CORINAIR Emission Inventory Guidebook. The quantity of waste burnt annually is also estimated, these estimates being based on information given in literature sources.

Recent activity data for some individual chemical waste, clinical waste and sewage sludge incinerators have been provided by the Environment Agency. These data have been used to improve the estimates for recent UK-level activity.

Emission estimates for animal carcass incinerators are taken directly from a Defra-funded study (AEA Technology, 2002) and are based on emissions monitoring carried out at a cross section of incineration plant. No activity data are available and so the emission estimates given in this report are assumed to apply for all years.

Emissions of CO, NO_x, SO_2 and VOC from crematoria are based on literature-based emission factors, expressed as emissions per corpse, and taken from US EPA (2008). Data on the annual number of cremations is available from the Cremation Society of Great Britain (2012).

Emissions from MSW incineration for the period 1990-1996 are reported split between 1A1a and 6C, in proportion to the tonnages of waste burnt with and without waste recovery respectively. The same methodology is used to estimate emissions for both types however, and details and CO2 factors are given in **Section 3.2.9**.

MSW and clinical waste incineration in the UK's Overseas Territories and Crown Dependencies is included in the CRF within the same categories as the UK data. The data are not reported separately since the same emission factors are applied to the OT/CD data as for the UK. Therefore no additional information (e.g. differences to emission factors) are obtained through reporting these data separately.

The inventory includes estimates for emissions of CO, NOx & VOC from small-scale burning of domestic and garden waste, for example on domestic grates and on garden bonfires. The estimates are very uncertain, being because of the need for expert judgements in order to derive any activity data from waste arisings data, and the lack of emission factors specific to this type of activity.

The tonnage of MSW burnt in incinerators is provided by the Cayman Islands, Bermuda and the Falklands. UK GHGI EFs were then applied to these activity data to estimate emissions from this sector. Waste incineration in Jersey and the Isle of Man is reported under 1A1a. It is assumed that this source is not occurring in the remaining territories.

8.4.3 Uncertainties and Time-Series Consistency

The Approach 1 (error propagation) uncertainty analysis in **Annex 7** provides estimates of uncertainty according to IPCC source category and gas.

8.4.4 Source Specific QA/QC and Verification

This source category is covered by the general QA/QC of the greenhouse gas inventory in **Section 1.6**.

8.4.5 Source Specific Recalculations

Details of and justifications for recalculations to activity data are given in **Table 8-5** and emission factors in **Table 8-6** below. For information on the magnitude of recalculations to Source Category 6C, see **Section 10**.

Table 8-5 6C Source specific recalculations to activity data since previous submission

IPCC Category	Source Name	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
			1990	2010	1990	2010		
6C	Incineration - clinical waste	Clinical waste	0.350	0.127	0.350	0.126	Mt	New activity data included for Gibraltar.

Table 8-6 6C Recalculations to Emission Factors since the previous inventory

IPCC Category	Source Name	Pollutant	Activity Name	2012 submission		2013 submission		Units	Comment/Justification
				1990	2010	1990	2010		
6C	Incineration	Carbon	MSW	75	75	83	94	kt / Mt	New time series of emission factors based on carbon content of waste.
6C	Incineration - chemical waste	N2O	Chemical waste			0.100	0.100	kt / Mt	New pollutant added in response to UNFCCC request. Factor quoted is the default quoted in the IPCC guidelines (2006)

8.4.6 Source Specific Planned improvements

Emission estimates for chemical waste incineration currently do not include the burning of chemical wastes in flares and it is unclear whether these emissions might be included in the estimates reported in 2B5. Should data on methane flaring become available within the pollution inventory for chemical waste incineration this data will be included in the inventory. No evidence has been found for any chemical waste incineration processes carried out in Scotland or Northern Ireland, and so emissions in these regions are assumed to be zero. The need to deal with significant gaps in the reported data means that estimates are quite uncertain. Emission estimates for clinical waste, animal carcass and sewage sludge incineration are also quite uncertain and ideally would be improved. However, all incineration processes are relatively minor sources of greenhouse gases and further development of the methodology is not a priority.

9 Other (CRF Sector 7)

9.1 OVERVIEW OF SECTOR

No emissions are reported in Sector 7.

10 Recalculations and Improvements

This section of the report summarises the recalculations and improvements made to the UK GHG inventory since the 2012 NIR (2010 inventory) was issued, including responses to reviews of the inventory. It summarises material that has already been presented and discussed in more detail in **Chapter 3** to **Chapter 9**. Table 8(b) of the CRF for each year also contains a summary of the recalculations since the previous inventory was submitted. The CRF was resubmitted in November 2011 following a UNFCCC review, recalculations checks within the CRF documents will show recalculations between November 2012 and this submission so will not necessarily be consistent with the NIR.

Each year, the UK greenhouse inventory is:

- ***Updated*** Existing activity data and/or emissions factors may be revised; and
- ***Extended*** The inventory includes a new inventory year.

Updating often entails revision of emission estimates, most commonly because of revision to the core energy statistics presented in the Digest of UK Energy Statistics (DUKES). The inventory also makes use of other datasets (see **Table 1.3** for a summary), and these too may be revised. Updating also covers adoption of revised methodologies. Updating, particularly involving revised methodologies, may affect the whole time series, so estimates of emissions for a given year may differ from estimates of emissions for the same year reported previously. Therefore comparisons between submissions should take account of whether there have been changes to the following:

- The methodology used to estimate emissions; and/or
- The activity data.

The time series of the inventory is *extended* by including a new inventory year - for example, the previous report covered the years up to and including 2010; this report gives emission estimates for 2010, and includes estimates for the year 2011 also.

The inventory may also be *expanded* to include emissions from additional sources if a new source has been identified within the context of the IPCC Guidelines and Good Practice Guidance, and there are sufficient activity data and suitable emission factors.

10.1 EXPLANATIONS AND JUSTIFICATIONS FOR RE-CALCULATIONS

Table 10.1 and **Table 10.2** summarise the recalculations that have occurred in estimates of the direct GHGs since the 2012 NIR (2010 inventory) was issued. The changes in emissions are net changes (the sum of any increases and decreases) in the source category, for the year 2010 (**Table 10.1**) and the base year (**Table 10.2**). **Table 10-3** gives details of where changes to methodological descriptions have been made and where these descriptions can be found in the main text of this document.

Table 8(a) s1, Table 8 (a) s2 and Table 8(b) of the CRF also present details of recalculations of emissions between the current and the previous inventory. The emissions are GWP weighted and are not shown to the same level of sectoral detail in **Table 10.1 or Table 10.2**.

The percentage change, due to re-calculation with respect to the previous submission, is calculated as follows:

Percentage change = 100 x [(LS-PS)/PS] ;

Where

LS = Latest Submission (2011 inventory; 2013 NIR); and
PS = Previous Submission (2010 inventory, 2012 NIR).

The percentages expressed in this way are consistent with those calculated in the CRF in Table 8 (a) s1 and Table 8 (a) s1.

For changes in earlier years' data, the corresponding CRF tables for that year should be referred to.

All revisions to source data and methods, and all recalculations that are reported in the latest UK GHG inventory are conducted by the inventory agency in agreement with the DECC GHG inventory management team; all major recalculations and systematic improvements to the UK GHG inventory are approved and managed via the NISC, with new outputs approved through the UK's arrangements for pre-submission review. The inventory improvement process that manages the prioritisation and implementation of revisions to inventory data and methods uses the guiding principles of the 1996 IPCC Guidelines and 2000 Good Practice Guidance to govern the decisions over whether to implement changes to inventory estimates or not. For the most significant recalculations to the UK GHG inventory reported in this submission, we have highlighted the key underlying justifications for making the change (see **Section 10.1.1**). The most common justifications for implementing changes that lead to recalculations are:

- ✓ Improved **accuracy** of the estimates, e.g. where underlying data from data providers has been revised (such as revisions to UK energy statistics), or where a less uncertain data source has come to light (such as the use of EU ETS activity data to inform energy allocations, in preference to UK energy statistics data sources). This justification also applies where we have sought to use more representative (ideally UK-specific) emission factors in estimation methods (such as the use of emission factors derived from EU ETS analysis in recent years of the inventory time series);
- ✓ Improved **transparency** of the inventory estimates, e.g. the restructuring of inventory data reporting to improve the level of detail of the UK inventory (such as the restructuring of 1A2 estimates in the 2012 submission, or the reporting of F-gas estimates by species wherever this is achievable);
- ✓ Improved **comparability** of the inventory estimates, e.g. the restructuring of inventory data reporting to enable UK estimates to align more closely with IPCC GLs and GPGs, (such as the re-allocations of limestone and dolomite data in the glass sector from 2A3 and 2A4 to 2A7, which was implemented in the 2012 submission to enable more harmonised data reporting across EU Member States).
- ✓ Improved **completeness** of the inventory estimates, e.g. the addition of emission estimates for new sources that come to light in the UK, or where new data for an existing source indicates that the activity data previously used in the method omitted some portion of the source emissions (such as the use of EU ETS activity data to

revise the estimates of emissions from refineries in the UK, where a gap in UK energy data reporting was identified through comparison against EU ETS data for the sector);

- ✓ Improved **consistency** of the inventory estimates, e.g. to implement new or revised methods that deliver estimates based on more consistent underlying data or assumptions across the time series (such as the revision to the waste water treatment and disposal method in 6B to use the available time series of sewage sludge disposal data rather than extrapolate from an historic industry study, using population data as the key activity to estimate emissions for later years in the time series).

10.1.1 GHG Inventory

Table 10-1 Re-Calculations of direct GHG emissions for the year 2010 in the UK 2013 NIR (2011 inventory) – including KP-LULUCF inventory.

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2011 inventory minus emissions in 2010 inventory)	Change in emissions (%) (Percentage change relative to the 2010 inventory)	Brief description of reasons for Re-Calculation
1A1			
CO_2	-419.9	0%	Main methodological revisions are to the offshore oil and gas industry. Improvements have been made in consultation with the DECC DUKES team following review recommendations due to outlier IEFs. Revisions also made to national energy statistics. See **Section 3.2.9** for more details.
CH_4	-6.7	-2%	
N_2O	-6.5	0%	
1A2			
CO_2	3060.3	5%	Main improvement is the addition of emissions from combustion of by-products at ethylene crackers, following UNFCCC review. Reduction in N_2O emissions is due to a correction to the off-road mobile combustion model. See **Section 3.2.10** for more details.
CH_4	16.3	8%	
N_2O	-66.2	-6%	
1A3			
CO_2	-1820.1	-2%	Most significant recalculation is due to a revision to national energy statistics. Improvements have also been made to the rail emissions model. This has especially effected N_2O. See **Section 3.2.11** for more details.
CH_4	-2.4	-3%	
N_2O	-250.9	-21%	
1A4			
CO_2	238.9	0%	Increase in emissions is due to a combination of improvements. The most significant recalculations are as follows: Firstly the inclusion of additional activity data for deep sea fishing in non-UK waters as a result of recommendations from the 2012 In Country Review. Revisions have also been made to natural gas activity data supplied for the Falkland Islands. See **Section 3.2.11** for more details.
CH_4	16.8	3%	
N_2O	2.5	0%	
1A5			
CO_2	-45.4	-2%	Error corrected in converting military fuel consumption data by financial year to calendar year. CO_2 EF also revised in

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2011 inventory minus emissions in 2010 inventory)	Change in emissions (%) (Percentage change relative to the 2010 inventory)	Brief description of reasons for Re-Calculation
CH_4	0.0	-2%	order to be consistent with other UK aviation spirit combustion.
N_2O	-0.4	-2%	
1B1			
CO_2	0.0	0%	Improved accuracy of UK-specific factors due to use of methane emissions data from more UK deep mine operators. Previous submission assumed data from UK Coal was representative of the whole industry. Now have around 90% coverage of the industry in deriving the emission factor. Emission estimates are also now included for charcoal production.
CH_4	291.3	16%	
N_2O	0.0	0%	
1B2			
CO_2	35.6	1%	Inclusion of gas leakage at point of use in domestic and commercial cooking appliances. This was following recommendation from the ERT. See **Section 3.3.2** for more details.
CH_4	7.9	0%	
N_2O	0.3	1%	
2A			
CO_2	843.4	15%	Main improvement is to activity data. Now consistent with EU ETS and PI emissions data.
2B			
CO_2	-26.1	-1%	The main improvement is a correction to the time series of emission from chemical industy – other to ensure completeness.
CH_4	10.4	14%	
N_2O	0.0	0%	
2C			
CO_2	-65.5	-4%	The main improvement has been a revision to energy statistics impacting on the CEFs generated from the carbon balance method. Steel production statistics have also been revised.
CH_4	0.0	0%	
N_2O	0.0	-1%	
HFCs	0.0	0%	
PFCs	0.2	0%	
SF6	0.0	0%	

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2011 inventory minus emissions in 2010 inventory)	Change in emissions (%) (Percentage change relative to the 2010 inventory)	Brief description of reasons for Re-Calculation
2E			
HFCs	0.0	0%	No recalculations have been made to emissions from this category.
PFCs	0.0	0%	
2F			
HFCs	74.3	1%	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory
PFCs	0.0	0%	
SF_6	-0.4	0%	
4A			
CH_4	71.6	0%	Main improvement is an increase in lamb lifespan from 6 to 8.1 months following 2012 In Country Review
4B			
CH_4	-109.5	-4%	Main improvements are to estimates for cattle. Feed digestibility revised and ash value updated.
N_2O	-8.2	0%	
4D			
N_2O	570.1	2%	Main improvement was to update UK histosols area to be consistent with estimates for the LULUCF sector. This was in response to 2012 In Country Review.
5A			
CO_2	119.9	-1%	Revised activity data on wildfires and inclusion of DOM in biomass burning
CH_4	-3.4	-42%	
N_2O	59.6	3100%	New activity data for drainage on forest soils.
5B			
CO_2	-177.6	-1%	Agricultural liming activity data updted.
CH_4	-0.2	-44%	

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2011 inventory minus emissions in 2010 inventory)	Change in emissions (%) (Percentage change relative to the 2010 inventory)	Brief description of reasons for Re-Calculation
N_2O	-73.2	-12%	
5C			
CO_2	-46.7	1%	Recalculations arise from the inclusion of the new wildfires emissions source, and adjustments to the deforestation activity data set (biomass and dead organic matter losses following deforestation are now estimated from country-specific biomass densities). Other small changes in emissions are described in **Section 7.4**.
CH_4	1.1	9%	
N_2O	5.9	495%	
5D			
CO_2	139.6	53%	The activity data for 2009-2010 was updated with the latest published information on peat volume sales (ONS 2011). Volumes for 2011 were assumed to be equal to those in 2010. Other small changes in emissions are described in **Section 7.5**.
CH_4			
N_2O	0.0	0%	
5E			
CO_2	33.5	1%	The recalculations arise mainly from adjustments to the deforestation activity data set (biomass and dead organic matter losses following deforestation are now estimated from country-specific biomass densities). Other small changes in emissions are described in **Section 7.6**.
CH_4	-1.5	-18%	
N_2O	-0.2	-18%	
5G			
CO_2	122.2	-3%	Minor revisions in the deforestation activity dataset resulted in changes in the pool of harvested wood products (from additions from deforestation). Emissions and removals for the OTs and CDs were previously all included in this category. These are now all reported in the relevant categories.
N_2O	-2.0	-100%	
6A			
CH_4	1.1	0%	Inclusion of emissions from Montserrat for the first time following recommendation from the ERT.
6B			
CH_4	1276.6	367%	The main recalculation is due to the inclusion of emission estimates from industrial wastewater following recommendation

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2011 inventory minus emissions in 2010 inventory)	Change in emissions (%) (Percentage change relative to the 2010 inventory)	Brief description of reasons for Re-Calculation
N_2O	58.2	5%	from the ERT. Other small changes in emissions are described in **Section 8.3**.
6C			
CO_2	5.9	2%	New activity data has been included for incineration of clinic waste in Gibraltar. Emissions for N2O have also been included from incineration of chemical waste following recommendation from the ERT.
CH_4	0.0	0%	
N_2O	4.4	9%	

Table 10-2 Re-Calculations of direct GHG emissions for the base year in the UK 2013 NIR (2011 inventory).

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2011 inventory minus emissions in 2010 inventory)	Change in emissions (%) (Percentage change relative to the 2010 inventory)	Brief description of reasons for Re-Calculation
1A1			
CO_2	-999.8	0%	Main methodological revisions are to the offshore oil and gas industry. Improvements have been made in consultation with the DECC DUKES team following review recommendations due to outlier IEFs. This particularly affected the early part of the time series. See **Section 3.2.9** for more details.
CH_4	-13.7	-6%	
N_2O	-1.1	0%	
1A2			
CO_2	2218.8	2%	Main improvement is the addition of emissions from combustion of by-products at ethylene crackers, following UNFCCC

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2011 inventory minus emissions in 2010 inventory)	Change in emissions (%) (Percentage change relative to the 2010 inventory)	Brief description of reasons for Re-Calculation
CH_4	3.6	1%	review. Reduction in N_2O emissions is due to a correction to the off-road mobile combustion model. See **Section 3.2.10** for more details.
N_2O	-118.4	-7%	
1A3			
CO_2	110.7	0%	Improvements have been made to the rail emissions model through the NISC Improvement Programme. This has especially effected N_2O. See **Section 3.2.11** for more details.
CH_4	-1.1	0%	
N_2O	-158.4	-11%	
1A4			
CO_2	43.6	0%	Inclusion of additional activity data for deep sea fishing in non-UK waters as a result of recommendations from the 2012 In Country Review. See **Section 3.2.11** for more details.
CH_4	6.6	0%	
N_2O	0.4	0%	
1B1			
CH_4	24.5	0%	Improved accuracy of UK-specific factors due to use of methane emissions data from more UK deep mine operators. Previous submission assumed data from UK Coal was representative of the whole industry. Now have around 90% coverage of the industry in deriving the emission factor. Emission estimates are also now included for charcoal production.
1B2			
CO_2	0.1	0%	Inclusion of gas leakage at point of use in domestic and commercial cooking appliances. This was following recommendation from the ERT. See **Section 3.3.2** for more details.
CH_4	35.5	0%	
2A			
CO_2	246.6	2%	Main improvement is to activity data. Now consistent with EU ETS and PI emissions data.
2F			
HFCs	0.1	0%	Inclusion of estimate for OTs and CDs within this category; update of estimate for OTs and CDs to be in line with latest inventory
4A			

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2011 inventory minus emissions in 2010 inventory)	Change in emissions (%) (Percentage change relative to the 2010 inventory)	Brief description of reasons for Re-Calculation
CH_4	140.5	1%	Main improvement is an increase in lamb lifespan from 6 to 8.1 months following 2012 In Country Review
4B			
CH_4	-110.0	-3%	Main improvements are to estimates for cattle. Feed digestibility revised and ash value updated.
N_2O	-6.1	0%	
4D			
N_2O	624.6	2%	Main improvement was to update UK histosols area to be consistent with estimates for the LULUCF sector. This was in response to 2012 In Country Review.
4F			
CH_4	0.4	0%	Updated N-C ratios and crop production data.
N_2O	1.7	2%	
5A			
CO_2	153.0	-1%	Revised activity data on wildfires and inclusion of DOM in biomass burning New activity data for drainage on forest soils.
N_2O	51.6	927%	
5B			
CO_2	20.8	0%	Agricultural liming activity data updted.
CH_4	0.0	5%	
N_2O	-11.6	-1%	
5C			
CO_2	-51.5	1%	Recalculations arise from the inclusion of the new wildfires emissions source, and adjustments to the deforestation activity data set (biomass and dead organic matter losses following deforestation are now estimated from country-specific biomass densities). Other small changes in emissions are described in **Section 7.4**.
CH_4	9.1	234%	
N_2O	14.0	3543%	

Source category and GHG	Change in emissions ($GgCO_2eq$) (Emissions in 2011 inventory minus emissions in 2010 inventory)	Change in emissions (%) (Percentage change relative to the 2010 inventory)	Brief description of reasons for Re-Calculation
5E			
CO_2	-69.2	-1%	The recalculations arise mainly from adjustments to the deforestation activity data set (biomass and dead organic matter losses following deforestation are now estimated from country-specific biomass densities). Other small changes in emissions are described in **Section 7.6**.
CH_4	-3.3	-33%	
N_2O	-0.3	-33%	
5G			
CO_2	16.7	-1%	Minor revisions in the deforestation activity dataset resulted in changes in the pool of harvested wood products (from additions from deforestation). Emissions and removals for the OTs and CDs were previously all included in this category. These are now all reported in the relevant categories.
N_2O	-0.1	-100%	
6A			
CH_4	2.5	0%	Inclusion of emissions from Montserrat for the first time following recommendation from the ERT.
6B			
CH_4	1398.4	487%	The main recalculation is due to the inclusion of emission estimates from industrial wastewater following recommendation from the ERT. Other small changes in emissions are described in **Section 8.3**.
N_2O	0.2	0%	
6C			
CO_2	64.9	5%	New activity data has been included for incineration of clinic waste in Gibraltar. Emissions for N2O have also been included from incineration of chemical waste following recommendation from the ERT.
CH_4	0.0	0%	
N_2O	9.0	19%	

Table 10-3 Changes in methodological descriptions

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS	RECALCULATIONS	REFERENCE
	Please tick where the latest NIR includes major changes in methodological descriptions compared to the previous year NIR	Please tick where this is also reflected in recalculations compared to the previous year CRF	If ticked please provide some more detailed information for example related to sub-category, gas, reference to pages in the NIR, etc
Total (Net Emissions)	We have made major updates to the methodological descriptions in the NIR in order to improve transparency		
1. Energy			Chapter 3
A. Fuel Combustion (Sectoral Approach)			
1. Energy Industries	√	√	
2. Manufacturing Industries and Construction	√	√	
3. Transport	√	√	
4. Other Sectors	√	√	
5. Other	√	√	
B. Fugitive Emissions from Fuels			
1. Solid Fuels	√	√	
2. Oil and Natural Gas	√	√	
2. Industrial Processes			Chapter 4
A. Mineral Products	√	√	
B. Chemical Industry	√	√	
C. Metal Production	√	√	
D. Other Production	√	√	
E. Production of Halocarbons and SF6	√	√	
F. Consumption of Halocarbons and SF6	√	√	
G. Other			
3. Solvent and Other Product Use			
4. Agriculture			Chapte r 6
A. Enteric Fermentation	√	√	
B. Manure Management	√	√	
C. Rice Cultivation	√	√	
D. Agricultural Soils	√	√	
E. Prescribed Burning of Savannas			
F. Field Burning of Agricultural Residues	√	√	
G. Other			

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	DESCRIPTION OF METHODS Please tick where the latest NIR includes major changes in methodological descriptions compared to the previous year NIR	RECALCULATIONS Please tick where this is also reflected in recalculations compared to the previous year CRF	REFERENCE If ticked please provide some more detailed information for example related to sub-category, gas, reference to pages in the NIR, etc
Total (Net Emissions)	We have made major updates to the methodological descriptions in the NIR in order to improve transparency		
5. Land Use, Land-Use Change and Forestry			Chapter 7
A. Forest Land	√	√	
B. Cropland	√	√	
C. Grassland	√	√	
D. Wetlands	√	√	
E. Settlements	√	√	
F. Other Land	√	√	
G. Other	√	√	
6. Waste			Chapter 8
A. Solid Waste Disposal on Land	√	√	
B. Waste-water Handling	√	√	
C. Waste Incineration	√	√	
D. Other			
7. Other (as specified in Summary 1.A)			
Memo Items:			
International Bunkers			Section 3.2.11
Aviation	√	√	
Marine	√	√	
Multilateral Operations			
CO2 Emissions from Biomass			

10.1.2 KP-LULUCF Actvities

3.3 Afforestation
New activity data has been used for afforestation and emissions from wildfires are now split between Afforestation and Land Management. This has caused a small decrease in Carbon emissions and an increase in CH_4 and N_2O emissions

3.3 Deforestation
Emissions from Deforestation in Northern Ireland; deforestation to cropland and liming on deforested land have been included for the first time

3.4 Forest Management
Forest Management areas have been adjusted to take into account new deforestation activity data and emissions from wildfires are now split between Afforestation and Land Management.

10.2 IMPLICATIONS FOR EMISSION LEVELS

10.2.1 GHG Inventory

Information at sector level is summarised in **Tables 10.1** and **10.3** above. The overall impact of all recalculations is an increase in emissions of 3,653 Gg CO_2 equivalent in the base year, and 3,935 Gg CO_2 equivalent in 2010.

An overview chart showing the sector level changes is set out below.

Figure 10-1 Time series of changes in GWP emissions between the inventory presented in the current and the previous NIR, according to IPCC source sector.

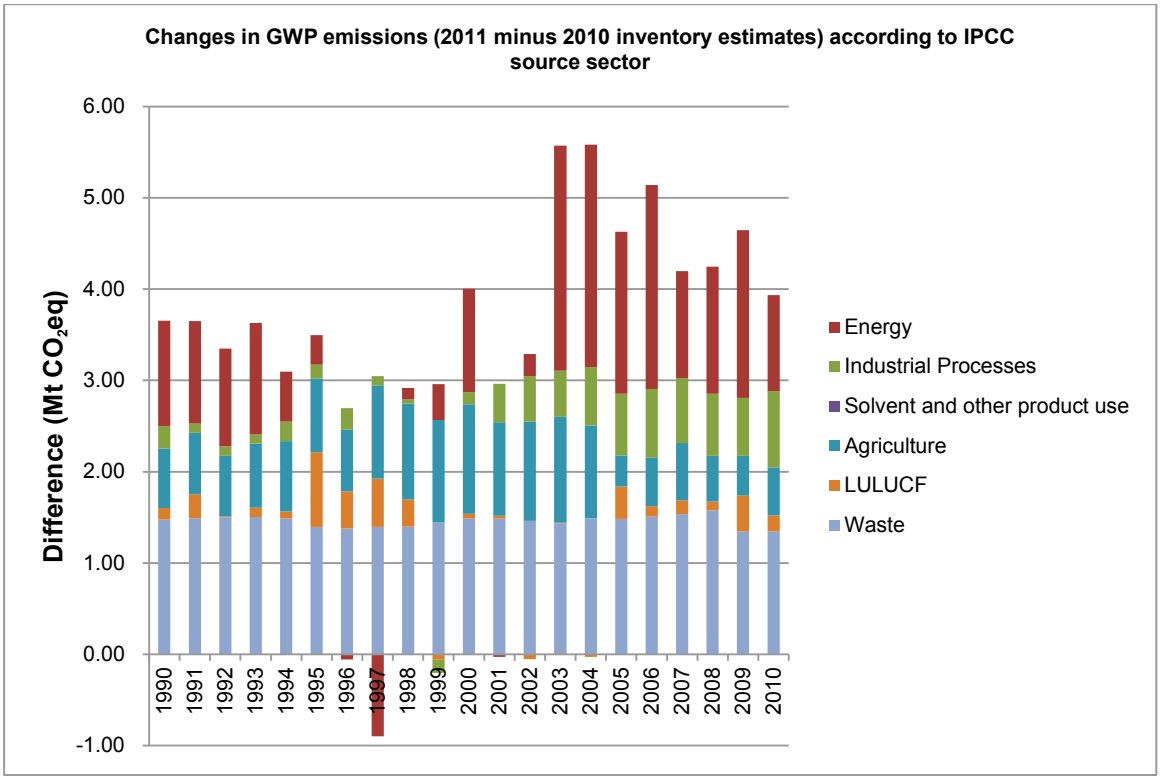
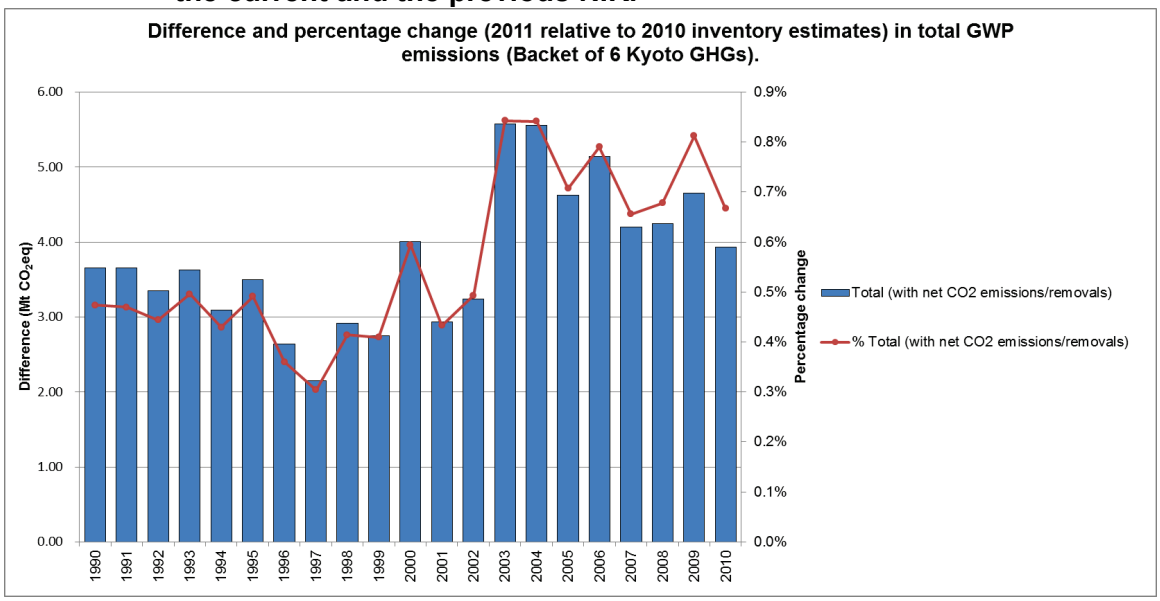


Figure 10.2 shows the net impact of all recalculations in absolute and percentage terms.

Figure 10-2 Time series of changes in total net GWP emissions, and percentage changes in total net GWP emissions, between the inventory presented in the current and the previous NIR.



10.2.2 KP-LULUCF Activities

Information on the reasons for recalculations is included in **Section 10.1.2** and **Section 11.3.1.4**. The net impact of these changes is a decrease of 142 Gg CO_2e in the base year, and a decrease of 197 Gg CO_2e in 2010.

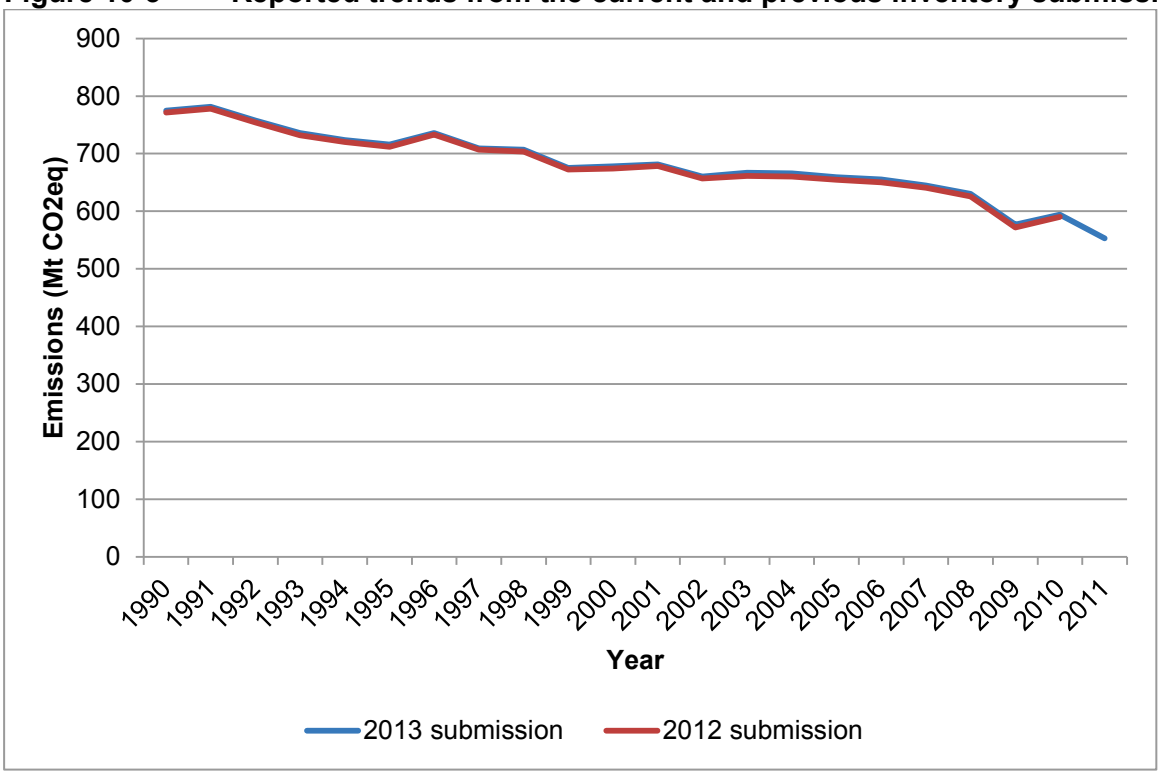
10.3 IMPLICATIONS FOR EMISSION TRENDS, INCLUDING TIME SERIES CONSISTENCY

10.3.1 GHG Inventory

There has been little change in the reported trend in emissions. The reported trend from 1990 to 2010 in the 2012 inventory submission was a decrease of 23.5%. The recalculated trend from 1990 to 2010, as presented in the 2013 submission is a decrease of 23.3%.

The chart below displays the trend from both the 2012 and 2013 submissions.

Figure 10-3 Reported trends from the current and previous inventory submissions



10.3.2 KP-LULUCF Actvities

Information on the reasons for recalculations is included in **Section 10.1.2** and **Section 11.3.1.4**. As the KP-LULUCF Inventory contains both emissions and removals of GHGs, expressing the change in trend from the base year to 2010 as a percentage difference is inappropriate.

10.4 RECALCULATIONS, INCLUDING IN RESPONSE TO THE REVIEW PROCESS, AND PLANNED IMPROVEMENTS TO THE INVENTORY

All recalculations to the inventory, including those made in response to the review process and other recalculation e.g. due to data revisions are described in detail within chapters 3-8, and are summarised in **Tables 10.1** and **10.2**. This section of the report summarises all recommendations from the review process, including where these have led to:

- recalculations
- changes in reporting in the NIR
- changes in reporting in the CRF
- planned improvements for future submissions

The UNFCCC conducted a Centralised Review of the 2012 greenhouse gas inventory submission (2012 NIR) in accordance with decision 22/CMP.1. In accordance with the conclusions of the Subsidiary Body for Implementation at its twenty-seventh session, the focus of the review was on the most recent (2012) submission. The review took place during September 2012 in London. A review report has not yet been received; however, improvements have been implemented based on comments provided during the review week and also in the Saturday Paper.

Table 10-4 provides an overview of the actions taken to improve the NIR and the inventory in response to the comments made by UNFCCC and EU Expert Review Teams, including reviews from 2011 and 2012. The table concentrates on the improvements that have been made to methods used to estimate emissions from the Key Categories and the steps taken to improve transparency of reporting from those Key Categories. Where actions have led to a recalculation or methodology change, these are described in Section 2.5 of this report.

10.4.1 GHG Inventory

Table 10-4 Brief Details of Improvements to the NIR and the Inventory in response to FCCC Reviews in response to the 2009 reviews.

Expert Review Team Comment	UK GHGI Actions	Time frame
Recommendations from the In Country Review: September 2012		
1A, 6C The fossil carbon emission factor for MSW used by the UK was identified as lower than the IPCC default, without sufficient justification.	A new time series of fossil carbon emission factors has been developed, based on the residual waste composition data used for the UK's landfill model. This better reflects the changing waste composition in the UK. The time series of values remains lower than the IPCC default.	The new time series has been incorporated in the 2013 submission.
1A2f Residual gases (a.k.a. other petroleum gases, OPG) produced in the refinery and petrochemical industries and ultimately used as a fuel in combustion processes have been identified as under-reported within the Digest of the United Kingdom Statistics (DUKES). The DUKES data has previously been used as activity data for the inventory estimates, but evidence from analysis of EU ETS data indicates that emissions from OPG use as a fuel are higher than inventory estimates based on DUKES. This matter was partly addressed in the 2012 submission of the United Kingdom, when new estimates of OPG combustion emissions based on EU ETS data for a number of UK sites were reported in IPCC sectors 1A1b (Refinery) and 1A2f (Other Industry). During the review, the ERT noted that a number of other facilities in the UK use OPG as a fuel and that there remained some under-reporting of OPG use in the UK energy statistics, and therefore the emissions for all gases from UK industrial combustion are underestimated for all years of the time series.	A new time series of OPG use and emissions has been generated, based on analysis of the underlying data for the UK energy statistics, ETS data and consultation with DECC energy statisticians, UK environmental regulators and plant operators. This OPG use is in addition to that reported in the UK energy statistics.	The new time series has been incorporated in the 2013 submission, with all new emission estimates allocated to 1A2f: Other industry for confidentiality reasons.

Expert Review Team Comment	UK GHGI Actions	Time frame
1A3b The United Kingdom uses the COPERT IV model for estimating CH4 and N2O emissions from road transportation. For CO2 emissions the United Kingdom scales the activity data from fuel consumption used in the model to the quantity of fuel sold (energy balance) which is in accordance with the Revised 1996 IPCC Guidelines. For CH4 and N2O emissions however there is no scaling of the fuel consumption, which – since the calculated fuel consumption in 2010 is lower than the quantity of fuel sold – leads to an underestimation of emissions from CH4 and N2O for 2010.	An explanation of the rationale for calculating and reporting emissions in this way was provided to the ERT. No changes to the calculations or reporting have been made to the 2013 submission, however this source is under review. Note that estimates are higher in some years and lower in others compared with emissions normalised to the fuel use totals.	Will be reviewed for the 2014 submission.
1A4d The shipping inventory developed by Entec (2010) provides estimates of shipping for journeys that can be classified as domestic, for journeys departing from or arriving at the United Kingdom ports on international journeys and for journeys passing through the United Kingdom shipping waters, but not stopping at the United Kingdom ports, nor using the fuels sold in the United Kingdom. Domestic journeys and fishing fuel consumption were subtracted from the total fuel consumption for shipping activities reported by the Digest of the United Kingdom Statistics (DUKES) and the resulting activity data was allocated as international navigation. Although this bottom up approach is very thorough, the ERT noticed that – since the scope of the Entec study was limited to the United Kingdom waters – activity data and resulting emissions (all gases) from shipping movements to and from the Overseas Territories are not included in this subcategory and the national total and therefore emissions from Domestic Navigation category are underestimated for all years of the time series.	A time series of emissions and fuel use from shipping movements between the UK and the Overseas Territories has been developed based on shipping movements from ports data.	The new time series has been incorporated in the 2013 submission.

Expert Review Team Comment	UK GHGI Actions	Time frame
1A4c Activity data and resulting emissions from fishing outside the United Kingdom waters are not included in the corresponding category and the national total and therefore emissions from category Agriculture/ Forestry/Fisheries are underestimated for all years.	A time series of fuel use and emissions from fishing outside of UK waters has been developed and is included in the 2013 submission.	The new time series has been incorporated in the 2013 submission.
2B1 The United Kingdom reported CO_2 emissions from Ammonia Production amounting 978.43 Gg in 2010. The ERT estimated CO_2 emissions based on the Revised 1996 IPCC Guidelines default emission factor (1.6 t CO_2/t ammonia produced) and the production of ammonia provided to the ERT (1084 kt in 2010) resulting in 1734.46 Gg CO_2. This shows that the Party's reported CO_2 emissions are likely underestimated. The NIR indicates that there are three ammonia production sites in the United Kingdom. The ammonia plants use natural gas as a feedstock, which is reported as 26.48 PJ in 2010 (probably including feedstock consumption in an acetic acid plant). The reported total ammonia production from the three plants is 1,080 kt. The ammonia plants are located in Ince, Hull and Billingham. During the review week, the United Kingdom provided to the ERT information from two ammonia plant operators, on the split of CO_2 emissions from natural gas used as fuel and from natural gas used in the process. The total process emission reported is 978.43 Gg CO_2 coming from Ince and Billingham ammonia plants. The ERT notes that the reported CO_2 emissions from industrial processes were based on emissions of two plants and not the three operating plants.	Additional information was supplied to the ERT, and the section on ammonia production in the NIR will be updated to aid transparency. The third operating ammonia plant, which the ERT noted that the UK were not reporting emissions for, uses a hydrogen (rather than natural gas) feedstock and therefore does not lead to CO_2 emissions. Emissions of CO_2 from ammonia production are therefore not underestimated; however efforts will be made to improve the transparency of the NIR.	Improved explanatory text will be provided in the 2013 full NIR

Expert Review Team Comment	UK GHGI Actions	Time frame
2B5 The United Kingdom reported CH_4 emissions from the category Other- Chemical Industry (All) amounting to 2.82 Gg in 2010. The value reported includes CH_4 emissions from chemical processes and waste treatment plants. The method used to calculate CH_4 emissions is not transparent due to lack of activity data and emission factors. In accordance with the additional information provided by the United Kingdom during the review week, CH_4 emissions from the category Other- Chemical Industry (All), including only the chemical plants, are greater than 2.82 Gg and therefore the ERT concludes that the reported CH_4 emissions for 2010 were underestimated.	The ERT were provided with full details of the IPPC reported data from all industry sectors that contribute to the UK GHGI estimates for 2B5. A small correction has been made to the emissions from this category to ensure that annual estimates include all emissions reported in the IPPC Regulators' inventories.	The new time series has been incorporated in the 2013 submission.
4D During the review week the ERT noted that there is a discrepancy in the area of cultivated histosols reported in the CRF Table 4.D and the Table 5.B (LULUCF sector). For the year 2010, Table 4.D reports the area of cultivated histosols as 39,200 ha, while Table 5.B. reports the area of lowland drainage as 150,000 ha. The ERT considers that this difference in the areas reported, could lead to an under-estimation of the N_2O emissions in the 4.D.1.5 Cultivation of histosols sub-category of approximately 430 Gg of CO_2 eq.	The area of histosols in the agriculture sector has been revised to be consistent with the data used for the LULUCF sector.	The new time series has been incorporated in the 2013 submission.
4D The ERT noted that N_2O emissions from agricultural soils are not estimated in the Overseas Territories (OT) and Crown Dependency (CD) for the complete time series.	A time series of emissions from sector 4D for the Overseas Territories and Crown Dependencies has been estimated based on FAO data and the IPCC Tier 1 methodology.	The new time series has been incorporated in the 2013 submission.
6A1 CH_4 emissions from solid waste disposal on land are not estimated for Montserrat, which is one of the Overseas Territories (OT), for all years of the time series in the United Kingdom inventory.	A time series of emissions from landfills in Montserrat has been calculated using the IPCC Tier 1 methodology.	The new time series has been incorporated in the 2013 submission.

Expert Review Team Comment	UK GHGI Actions	Time frame
6B1 and 2B5 The ERT noted a lack of transparency in the reporting of CH_4 emissions from the Industrial Wastewater Handling for the entire time series in the United Kingdom inventory. The emissions from industrial wastewater (waste water and sludge) were reported as included elsewhere (under the industrial processes sector), however there was no description in the NIR or CRF tables in which category under the industrial sector these emissions were included. During the review week, the United Kingdom explained that those emissions were included in Chemical Industry (All) (2.B.5) under the Chemical Industry category within other CH_4 emissions from the chemical industry, however it has not been clarified which industries were considered, which emission factors and parameters and methods were used in calculations and also the total amount of CH_4 emissions related to the industrial wastewater that was included under 2.B.5. Because the amount of CH_4 emissions reported under 2.B.5 is small and the lack of transparency of the information the ERT was not able to assess whether CH4 emissions from industrial wastewater are not underestimated.	Emissions from industrial waste water treatment are included under 6B2, where the waste water is treated in the municipal system, or under sector 2, predominantly in sector 2B5 where there is onsite waste water treatment. Reporting under 2B5 is based on operator returns to the Regulators' inventories, and since onsite waste water treatment is included under the IPPC permits for these sites, no separate estimates have previously been made for this source. However, the ERT noted that the emissions reported under 2B5 looked to be too small, and also that the method was not transparent. Therefore, a new time series of emissions from industrial waste water treatment, based on a combination of UK specific data and IPCC defaults has been estimated and included in the inventory. We believe this leads to a small double count, but it has been included to provide a conservative estimate.	The new time series has been incorporated in the 2013 submission.
6C N_2O emissions from chemical waste incinerated are not estimated for all years of the time series in the United Kingdom inventory (reported as "NE").	An emission factor for N_2O has been identified and included in the current inventory.	The new time series has been incorporated in the 2013 submission.
1A1a Emissions of CH_4 and N_2O from waste oils in power stations were identified as not estimated.	Although no default emission factors for waste oils are available in the IPCC guidelines, the emission factors for fuel oil have been applied to the waste oil activity data to ensure completeness of reporting for the power station sector.	The new time series has been incorporated in the 2013 submission.
1B2b Emissions from natural gas leakage at the point of use were noted as missing for cooking and gas fires.	Emissions from leakage at the point of use for gas boilers were incorporated into the 2010 inventory. Additional emissions from cooking and gas fires have now also been incorporated.	The new time series has been incorporated in the 2013 submission.

Expert Review Team Comment	UK GHGI Actions	Time frame
ESD review: April – August 2012		
4A The CH_4 IEF of dairy cattle increased 2004 to 2005 by 15.3% (from 97.7kg CH_4/head to 112.7kg CH_4/head). The GE intake increased from 248 MJ in 2004 to 286 MJ in 2005 (or by 15,3%). The milk yield increased only by 3.3% 2004-2005. The sharp increase of GE intake is mainly due to the increased live weights of dairy cattle which increased by 44.1% from 2004 to 2005. The approach used by the United Kingdom resulted in a strange trend with a peak in 2005 and declining emissions in the following year. This indicated an overestimation in the year 2005.	The United Kingdom provided a revised estimate for the time series including 2005. This was accepted by the TERT.	New data for 2005 submitted as part of the ESD review. A recalculated time series is included in the 2013 submission to address this issue.
2A2 For process emissions from lime production, the CRF data in 2.A.2. and the additional data provided for the EU ETS do not match well while all other emission categories for cement and lime compare well. This difference for process emissions from lime production also explains the difference in total emissions between CRF and EU ETS data for cement and lime production (CRF emissions are lower). The emissions from lime production are also much lower for 2009 in the 2012 submission than the emissions reported in the 2011 submission. Therefore, CO_2 emissions from lime production seem to be underestimated.	A revised time series for this source was provided to the TERT for the period 2005-2010 using data from the EU ETS. The process emissions from the decarbonisation of limestone and dolomite in the industry were previously based on data from the British Geological Survey. As noted by the TERT, the ETS data set indicates higher use of limestone and dolomite compared to BGS estimates. The revised estimates are consistent with the ETS data.	A recalculated time series (including emissions back to 1990) has been included in the 2013 submission.
1A There are significant differences between biomass combustion reported to EUROSTAT and in the CRF (around 20 % more in EUROSTAT data). The differences mainly occur in 1.A.2.f.	In response to a question raised by the TERT during the review, the United Kingdom acknowledged these differences and explained that efforts are made to reconcile the reporting of biomass in the CRF and to EUROSTAT. Our investigation indicated that biomass use (energy data and emissions) from autogenerators was missing from the inventory. The revised estimates therefore cover methane and N_2O emissions from autogenerator use of biomass. The estimates are based on DUKES data and IPCC default emission factors.	A recalculated time series (including emissions back to 1990) has been included in the 2013 submission.

Expert Review Team Comment	UK GHGI Actions	Time frame
Expert Review Team Comment	UK GHGI Actions	Time frame
Recommendations from ARR Report : March 2012		
The ERT identifies the following cross-cutting issues for improvement:		
Strengthen the efforts to implement the recommendations of previous review reports, especially those that had already been reiterated from the review before:		
Including, in the main body of the NIR, a complete discussion on completeness	As well as the completeness table in Annex 5, a short discussion on completeness is now included in each methodological chapter.	Included in 2012 submission
Allocating emissions from fuels used in manufacturing industries and construction to the appropriate subcategories	Emissions from fuels used in manufacturing industries are now reported in the appropriate categories where possible. See Section 3.2.7 for more details.	Included in 2012 submission
Reporting emissions of F-gases by species	Where available, speciated emissions of f-gases are reported. Unspeciated emissions are reported for some of the emissions of fugitive PFCs from manufacture, where speciated data are not available.	Speciated emissions, within the relevant sectors, have been reported for the Overseas Territories and Crown Dependencies in the 2013 submission. Unspeciated data are still reported for PFC production and potential emissions.
Improving the reporting on the OTs and CDs by including information on the methods and data used for estimating their emissions and consistent reporting across categories and sectors	More description has been included in the NIR on the methods and data used for estimating these emissions. Where it is possible to include OT and CD emissions within main sectors (not reporting as 'other') this has been done and stated as such in the main chapters. The NIR is currently being restructured to improve transparency.	Further information has been included in the 2012 submission. The 2013 full NIR has been restructured to ensure better transparency of reporting for all emission sources, including those from the Overseas Territories and Crown Dependencies.

Expert Review Team Comment	UK GHGI Actions	Time frame
Undertaking a qualitative analysis to ensure that categories which are particularly significant in level or trend are identified as key categories	A qualitative analysis is conducted annually to ensure significant categories are identified. No additional key categories were identified, but we have improved the reporting in the NIR to clarify how the qualitative analysis is conducted and the outcomes from it.	Description of qualitative analysis included in the full UK NIR (2012).
Including information on the time frame for addressing the recommendations of the review activities	Where possible, the time frame for addressing recommendations is included in the NIR.	Included in **Table 10-4** of the full UK NIR (2012).
Estimating emissions from wildfires on deforestation lands or provide evidence that wildfires do not occur	The assessment of a fire incidence dataset and the potential of remote sensing for reporting wildfires is now underway. New data for UK wildfires is being examined and we will report emissions for this category in the 1990-2011 inventory.	Included in the 2013 submission
Improve reporting of KP-LULUCF to ensure complete, accurate and unbiased reporting of KP-LULUCF activities on all lands in the United Kingdom	We have used new activity data to update the deforestation estimates for all countries in the UK. Methods are fully explained in Annex 3.7. We have used NFI data in the latest submission where available, but estimates of woodland loss from the NFI are still being assessed by the Forestry Commission. There is very limited forest area information for the OTs and CDs and the FAO Forest Resource Assessment 2010 reports that there has been no change in the forest area of these territories since 1990 (section 11.2.1). If/when new data becomes available we will include it in the next submission.	Part complete - more information included in 2013 submission.
Improve the description of recalculations by providing clear documentation and explanations on the justifications used for the changes made in methodologies, assumptions, data and parameters, and also ensure that any recalculation performed leads to a real improvement of the inventory	All method changes feed into the inventory through the improvement programme and are approved by the NISC at the pre-submission review. Additional descriptions have been included within the main chapter of the NIR on the reasons for recalculations and additional checks have been performed to ensure these descriptions are consistent in chapter 10 as in the methodology chapters.	Improvements have been made to the text in the 2012 submission. The 2013 full NIR includes more detailed tables explaining recalculations within each of the relevant chapters.

Expert Review Team Comment	UK GHGI Actions	Time frame
Continue to strengthen QC procedures at the stage of inventory compilation to avoid erroneous entries in CRF tables and mistakes in the text of the NIR	All submissions now undergo a 'knowledge leader check' where a senior member of the team who has not had the responsibility of compiling the CRF, or performing any of the initial cross checks, checks the outputs to ensure consistency with the NIR and our internal database.	Additional checks have been implemented for the 2012 and 2013 submissions; the additional checks for 2013 are described in **Section 1.6** of this report.
Improve the transparency of the inventory regarding the presentation of information on OTs and CDs in the CRF (e.g. include distinct AD and emissions from OTs and CDs under waste incineration) and the description of the geographical coverage for each reported category in the NIR	More description has been included in the NIR on the methods and data used for estimating these emissions. Where it is possible to include OT and CD emissions within main sectors (not reporting as 'other') this has been done and stated as such in the main chapters. The NIR is currently being restructured to improve transparency.	The improvement programme includes trying to obtain more detailed information, particularly for the waste sector for the 2013 submission. The re-structured NIR for the 2013 submission will improve transparency of reporting across all source of emissions including those from the Overseas Territories and Crown Dependencies.
Continue to improve the consistency and appropriateness of notation keys usage	All submissions now undergo a 'knowledge leader check' where a senior member of the team who has not had the responsibility of compiling the CRF or carrying out initial cross checks, checks the outputs to ensure consistency with the NIR and our internal database. A full review of all notation keys, tiers and emission factors reported in the CRF has been carried out for the 2013 submission to improve transparency, consistency and accuracy of reporting.	Full review carried out for the 2013 submission.
In the course of the review, the ERT formulated a number of sector-specific recommendations relating to the transparency and accuracy of the information presented in the United Kingdom's annual submission. The key recommendations are that the United Kingdom:		

Expert Review Team Comment	UK GHGI Actions	Time frame
Sector 1 and Sector 6 Increase the transparency on reported recalculations in the energy and waste sector as follows: recheck the new data and the changes in the methods, assumptions and parameters used in the estimates and further justify those in the NIR or return to the previous values (e.g. for solid waste disposal on land), until ensuring sufficient evidence to justify the changes; provide justification, description and references for the new EF for CH4 from wastewater handling and ensure it represents the United Kingdom as a whole	Additional text has been included in the waste chapter to explain the rationale for the recalculations performed in the 2011 NIR. The text on recalculations throughout the report has been cross checked with the information presented in Chapter 10. Further information on the rationale for making recalculations has been included throughout the report, and in Section 10.1	Additional text has been included in the 2012 submission.
Sector 1 and Sector 2 Improve the information provided on the treatment of feedstocks and nonenergy use of fuels in the inventory	The descriptions in the NIR and inclusion in the CRF have been checked and improved for the 2012 submission.	Additional text has been included in the 2012 submission.
2F Provide the necessary information on the model used to calculate the actual emissions of HFCs from consumption of halocarbons and SF6 (e.g. the EFs used in the model and the rationale for the selection of those values)	The model for estimating emissions of HFCs from refrigeration has been improved for the 2012 submission and more information included in the NIR.	Additional text has been included in the 2012 submission.
4D Follow the methodology described in the IPCC good practice guidance for the calculation of N2O emissions from agricultural soils	Emissions from agricultural soils have been recalculated in line with the IPCC GPG.	Recalculation has been made - additional text has been included in the 2012 submission.
Sector 4 Improve the transparency of the agriculture sector by including more information on country-specific EFs and other parameters, such as the lifespan of lambs in the NIR	Additional text on country specific parameters has been included in Annex 3.	Additional text has been included in the 2012 submission.

Expert Review Team Comment	UK GHGI Actions	Time frame
KP-LULUCF Ensure that there is a full representation of land areas under deforestation by including Northern Ireland, the OTs and CDs for the entire time series (KP-LULUCF)	We have used new activity data to update the deforestation estimates for all countries in the UK. Methods are fully explained in Annex 3.7. We have used NFI data in the latest submission where available, but estimates of woodland loss from the NFI are still being assessed by the Forestry Commission. There is very limited forest area information for the OTs and CDs and the FAO Forest Resource Assessment 2010 reports that there has been no change in the forest area of these territories since 1990 (section 11.2.1). If/when new data becomes available we will include it in the next submission.	Part complete - more information included in 2013 submission.
Sector 6 Improve the completeness with respect to unaccounted emissions from the OTs under the waste sector	More description has been included in the NIR on the methods and data used for estimating these emissions. Where it is possible to include OT and CD emissions within main sectors (not reporting as 'other') this has been done and stated as such in the main chapters.	Emissions from landfill and waste water treatment have been included in the 2013 submission, along with emissions from agricultural soils in the Overseas Territories and Crown Dependencies.
6A1 Collect survey data for CH4 recovery and update the AD in order to avoid a possible overestimation of recovered CH4 and provide detailed information on the data	More data on the amounts of landfill gas flared is now becoming available from the UK's environmental regulators, but the dataset is not sufficiently complete to be regarded as representative of the UK landfill sector. More research has been commissioned by UK Government to look at this issue and develop a more complete dataset, to help inform future inventory estimates.	Additional text has been included in the 2012 submission.

10.4.2 KP-LULUCF Estimates

Table 10-5 Brief Details of Improvements to the KP-LULUCF estimates in response to FCCC Reviews in response to the 2009 reviews.

Expert Review Team Comment	UK GHGI Actions	Time frame
Improve reporting of KP-LULUCF to ensure complete, accurate and unbiased reporting of KP-LULUCF activities on all lands in the United Kingdom	We have used new activity data to update the deforestation estimates for all countries in the UK. Methods are fully explained in Annex 3.7. We have used NFI data in the latest submission where available, but estimates of woodland loss from the NFI are still being assessed by the Forestry Commission. There is very limited forest area information for the OTs and CDs and the FAO Forest Resource Assessment 2010 reports that there has been no change in the forest area of these territories since 1990 (section 11.2.1). If/when new data becomes available we will include it in the next submission.	Part complete - more information included in 2013 submission.

11 KP-LULUCF

11.1 GENERAL INFORMATION

Emissions sources	Forest Management Afforestation Forest Land
Gases Reported	CO_2, CH_4, N_2O
Methods	NA
Emission Factors	NA
Key Categories (Trends)	NA
Key Categories (Level)	NA
Key Categories (Qualitative)	NA
Overseas Territories and Crown Dependencies Reporting	OTs and CDs are included at Tier 1 level
Completeness	
Major improvements since last submission	

11.1.1 Definition of forest

The UK has chosen the following definition of forest and single minimum values (also set out in table NIR.1).

A definition of 'forest' as agreed with the Forestry Commission comprising:

- a minimum area of 0.1 hectares;
- a minimum width of 20 metres;
- tree crown cover of at least 20 per cent, or the potential to achieve it;
- a minimum height of 2 metres, or the potential to achieve it.

This definition includes felled areas awaiting restocking and integral open space (open areas up to 1 hectare) (Forestry Statistics 2010, section 11.1).

These single minimum values are used for reporting UK forestry statistics (Forestry Commission, 2010) and the UK's greenhouse gas inventory submitted under the UNFCCC. The definitions are consistent with information provided by the UK to the FAO. If an international enquiry uses a different minimum definition, for example 0.5 ha in the Global Forest Resource Assessment 2010, the UK areas are adjusted to this different definition (FAO, 2010). A small area of forest in the UK's Crown Dependencies and Overseas Territories is included in the total areas. The Global Forest Resource Assessment 2010 reports for these countries are prepared by the UK's Forestry Commission, so areas and definitions are consistent with those in the UK.

A new National Forest Inventory (NFI) has been undertaken in Great Britain (Forestry Commission 2011). This uses a different minimum area of 0.5 hectares and a lower integral open space threshold of 0.5 ha (as opposed to 1 ha), which requires a negative adjustment to areas. However, the main differences in 2010 GB woodland cover between the NFI (2982 kha) and previous estimates (2757 kha, Forestry Statistics 2010) arise from identified errors in the previous woodland survey, particularly the under-estimate of woodland areas between 0.5 and 2 hectares. Estimates of woodland loss are still being assessed, which will affect the total woodland area. The NFI area estimates are not used for this inventory submission, but will be used once woodland loss estimates are confirmed.

11.1.2 Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

The UK has chosen to elect Forest Management (FM) as an activity under Article 3.4. In accordance with the Annex to Decision 16/CMP.1, credits from Forest Management are capped in the first commitment period. For the UK the cap is 0.37 MtC (1.36 $MtCO_2$) per year, or 6.78 $MtCO_2$ for the whole commitment period.

11.1.3 Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

The areas of forest land reported for AR and FM under the Kyoto protocol are broadly equivalent to the area reported as producing emissions under 5A Forest Land (Figure 11.1). The data sources and methods are the same, but the split between 5A1 and 5A2 is based on a 20-year transition period rather than a fixed point of 1990 (as for AR and FM).

Definitions are consistent with those used in the UNFCCC GHGI. The Afforestation/Reforestation area is land that has been converted to forested land since 1990 (inclusive). However, the Forestry Commission (the state forestry agency) report new planting by 'financial years', which run from 1st April to 31st March. In order to be compatible with the requirement to demonstrate that activities under Article 3.3 began on or after 1st January 1990, it is necessary to adjust the planting figures (Forestry Commission, pers. comm.). For example, 1990 will contain planting reported in 1990 (1st April 1989-31st March 1990) and 1991 (1st April 1990-31st March 1991). Therefore, the area reported for Article 3.3 Afforestation/Reforestation in 1990 is the sum of 25% of 1990 planting and 75% of 1991 planting, and so on to the present. The numbers reported in the UNFCCC GHGI are not adjusted (Figure 11.2): in 2011 the area of forest established since 1990 was 314,652 ha in the UNFCCC GHGI and 308,598 ha under Article 3.3 Afforestation.

Figure 11-1 **Area of forest in Article 3.3 Afforestation and Article 3.4 Forest Management compared with area of forest established since 1921 in UNFCCC Sector 5A Forest Land**

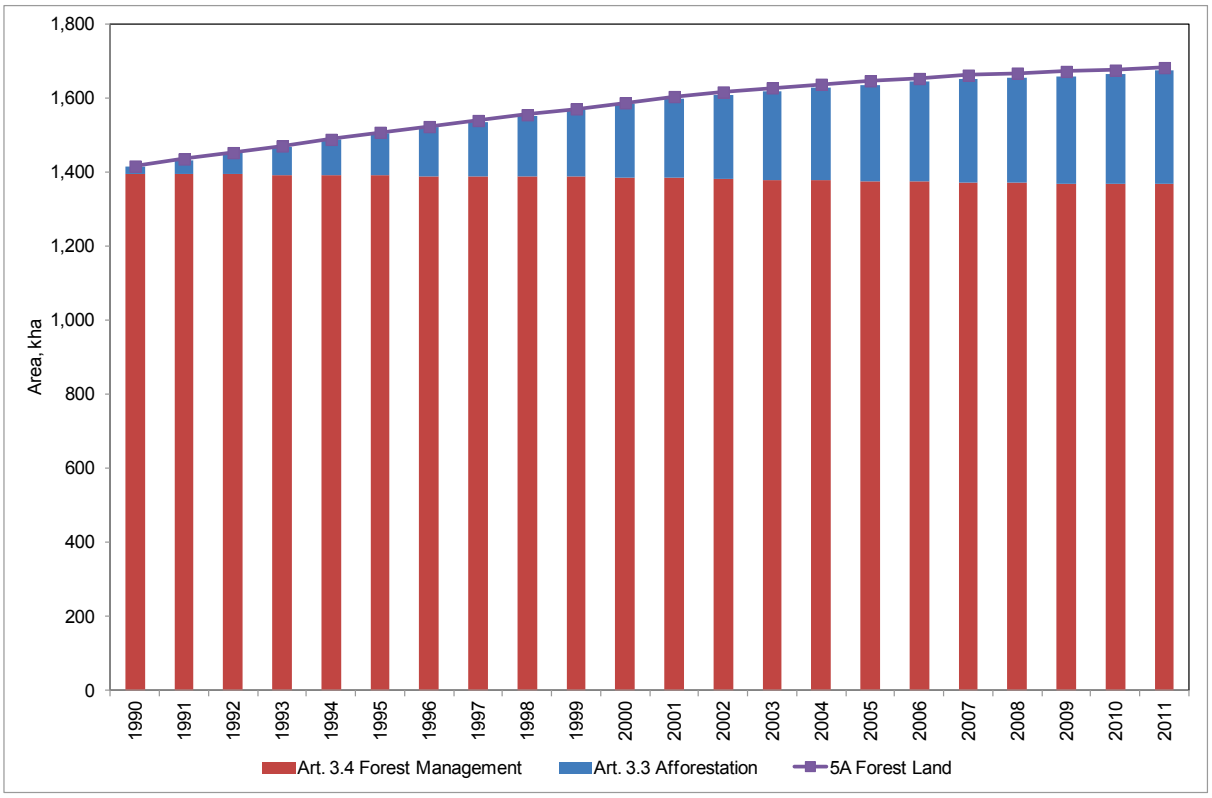
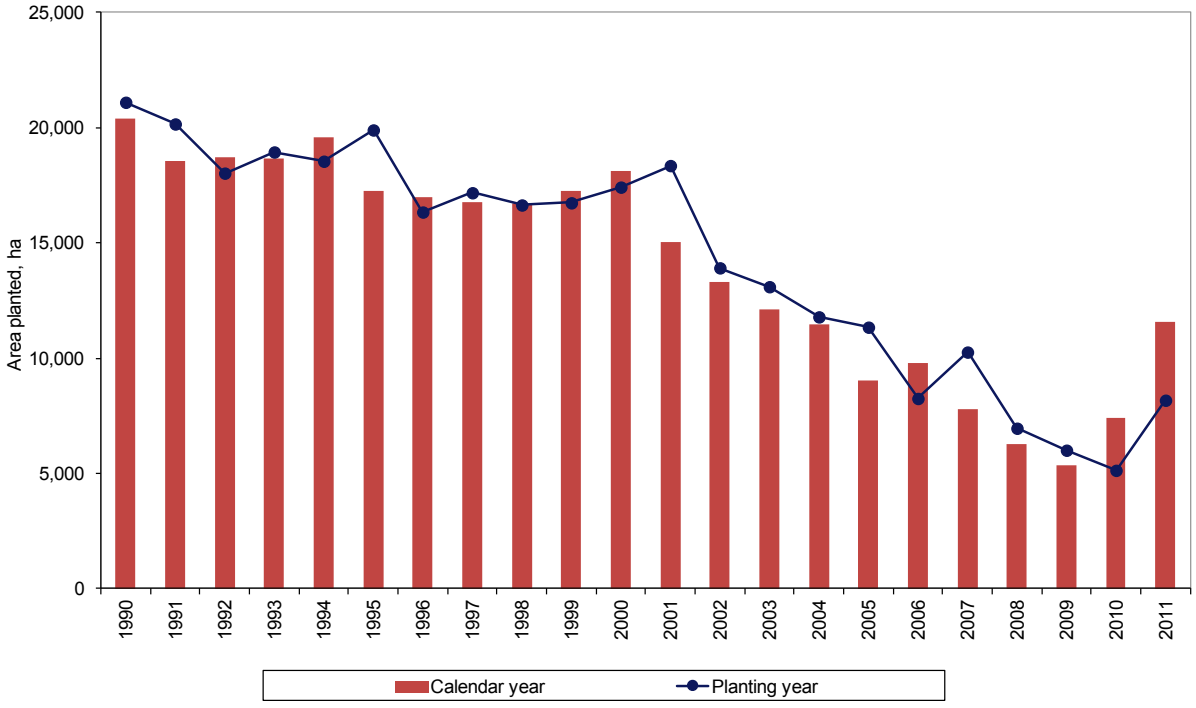


Figure 11-2 **UK afforestation since 1990 in the UNFCCC GHGI (by planting year) and in Article 3.3 (adjusted by calendar year)**



Deforestation since 1990 is taken to be the land area permanently converted from forest land to cropland, grassland or settlement. Areas of annual forest conversion are reported in the UNFCCC GHGI (under 5B2.1, 5C2.1 and 5E2.1, and the cumulative total 1990-2011 matches the area reported under Article 3.3 Deforestation (28.71 kha).

New estimates of woodland loss from the National Forest Inventory have yet to be reconciled with inventory reporting, but the Forestry Commission are undertaking further work in this area. Woodland loss in the NFI is defined as an identifiable permanent removal of woodland cover to change the land use, where the remaining trees on a site no longer have the potential to achieve a minimum coverage of 20% (Forestry Commission 2011). A definitive land use change, such as construction or quarrying is registered as an immediate loss. However, where tree removal is not immediately identifiable as land use change, e.g. during habitat restoration, woodland loss is not registered until permanent change is confirmed after ten years. The area of confirmed woodland loss (unequivocal permanent removal of woodland cover) for Great Britain between 1995-98 and 2010 in the NFI is 498 hectares, although only areas over 5 hectares (England and Wales) and over 20 hectares (Scotland) have been assessed to date (Forestry Commission 2011). The area of confirmed woodland loss will increase significantly once smaller areas of loss are examined. Estimates of intended woodland removal for wind-farm development and habitat restoration over the last decade amount to at least 20-30,000 hectares, which are more comparable with the estimates of deforestation currently used in the KP-LULUCF inventory of 19-22,000 hectares in Great Britain between 1995/98 and 2011.

The Forest Management area is the area converted to forest land between 1921 and 1989 (1,398.71 kha), adjusted to reflect losses from deforestation 1990-2011, giving a total of 1370.93 kha in 2011. In the UNFCCC GHGI the deforestation area is deducted from the 5A1 Forest remaining Forest Land area, and carbon stock changes are adjusted accordingly. The area of Forest Management and the area of post-1921 5A1 Forest remaining Forest are comparable in 2010 at 1372 kha, as the area of 5A1 in 2010 will include all forest planting between 1921 and 1990.

The afforestation/reforestation datasets are provided by the Forestry Commission and the Forest Service of Northern Ireland (the national forestry agencies) and are consistent with the definition of forest given above. New planting can use planting/seeding or natural colonisation. Data come from administrative systems (state forests) and grant schemes (other woodland) (Forestry Statistics 2012). Areas of planting that are not state-owned or grant-aided (i.e. whether these woodlands are explicitly managed is unknown) are not included in the GHGI or Article 3.3 AR. It is estimated that these contribute less than 0.4 kha annually (possibly an underestimate due to incomplete reporting, according to the Forestry Commission).

There is an assumption of restocking after harvesting, although open habitat can make up 13-20% of stand area on restocking (so stocking density is reduced from its previous level). Therefore, Afforestation and Reforestation under Article 3.3 can be considered together. Thinning is considered to be part of the normal forest management regime. A felling license is required for felling outside the national forest estate; there is a legal requirement to restock under such a license unless an unconditional felling license is granted (in which case this would be formally reported as deforestation). Information on deforestation activities is assembled from data provided by the Forestry Commission and by the Ordnance Survey (the national cartographic agency) through the UK government (**Chapter 7**). To the best of knowledge, these definitions have been applied consistently over time, although larger uncertainties are associated with deforestation estimates compared with afforestation estimates.

Although a number of Overseas Territories and Crown Dependencies that have joined the UK's instruments of ratification to the UNFCCC and the Kyoto Protocol, only the Isle of Man and Guernsey have suitable forest area data to enable the estimation of emissions for Afforestation and Forest Management. For the other countries, we are guided by what has been compiled for the FAO Forest Resource Assessment 2010 reports (with the assistance of the UK Forestry Commission). These state that there has been no change in the forest areas of these islands since 1990 and only the Cayman Islands and the Isle of Man report forest areas over 1000 ha.

Deforestation in the Overseas Territories and Crown Dependencies cannot be estimated due to a lack of activity data (these countries are so small that global datasets are of no help). In the absence of suitable data, the UK rate of deforestation was applied (area of deforestation/total forest area), which gave an estimated annual deforestation rate in the whole area of the Overseas Territories and Crown Dependencies of <0.003 kha per year. Therefore Deforestation in the Overseas Territories and Crown Dependencies is noted as Not Occurring.

11.1.4 Precedence conditions and hierarchy among Art. 3.4 activities

Not applicable, as only Forest Management has been elected under Article 3.4.

11.2 LAND-RELATED INFORMATION

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The UK uses IPCC Approach 3 (GPG-LULUCF) for tracking areas of afforestation and forest management on a spatially explicit basis. Deforestation areas are tracked using a mixture of Approach 2 and Approach 3 as several sources of information are used: deforestation is identifiable in all sources but the locations are not spatially explicit. The data sources and methodology can detect a land use change at a resolution consistent with the forest definition in **Section 11.1.1** (0.1 ha).

ARD and FM are reported at the level of the four countries of the UK: England, Scotland, Wales and Northern Ireland, and the combined area of the Overseas Territories and Crown Dependencies (GPG LULUCF Reporting Method 1). There is sufficiently detailed data to allow UK carbon stock changes for Article 3.3 AR and Article 3.4 FM land to be reported for 20x20km units, but not for the reporting of other emissions or Article 3.3 Deforestation carbon stock changes.

11.2.2 Methodology used to develop the land transition matrix

The land transition matrix is shown in Table NIR 2 (**Table 11-1**). The same data sources are used for the UNFCCC greenhouse gas inventory and emissions/removals under Articles 3.3 and 3.4. National planting statistics from 1921 to the present are provided by the Forestry Commission and the Northern Ireland Forest Service for each of the countries in the UK. Areas planted since 1990 in this dataset are used in Article 3.3 Afforestation/ Reforestation (Figure 11.3). There is currently no detailed information on the age and type of forests subject to deforestation and it is assumed that areas that have been afforested since 1990 will not have been deforested during this period. Estimates of areas in Article 3.3

Deforestation (Figure 11.4) are made using Unconditional Felling Licences and the Land Use Change Statistics (LUCS), a survey of land converted to developed use. Gap-filling is done using Countryside Survey land use change data. Further information on these data sources is in Chapter 7 and a summary is given in **Table 11-2.**

The area of Article 3.4 Forest Management land is the area of forest planted between 1921 and 1990, adjusted to take account of the area lost by deforestation (Figure 11.5). The area of Other Land in table NIR 2 is balanced so that the total area adds up to the land area reported for the UK and Overseas Territories and is constant for all years.

Table 11-1 Table NIR 2 of land area and changes in land areas in 2011 (including area of Overseas Territories and Crown Dependencies)

To current inventory year (2011)			Article 3.3 activities		Article 3.4 activities	Other	Total (beginning of year)
From previous inventory year (2010)			Afforestation and Reforestation	Deforestation	Forest Management		
Article 3.3 activities	Afforestation and Reforestation	kha	297.00	0.00			297.00
	Deforestation			27.49			27.49
Article 3.4 activities	Forest Management			1.22	1,370.93		1,372.16
Other			11.60	0.00	0.00	24,041.42	24,053.02
Total (end of year)			308.60	28.71	1,370.93	24,041.42	25,749.66

Figure 11-3 Forest area planted since 1990 in the countries, Overseas Territories and Crown Dependencies of the United Kingdom

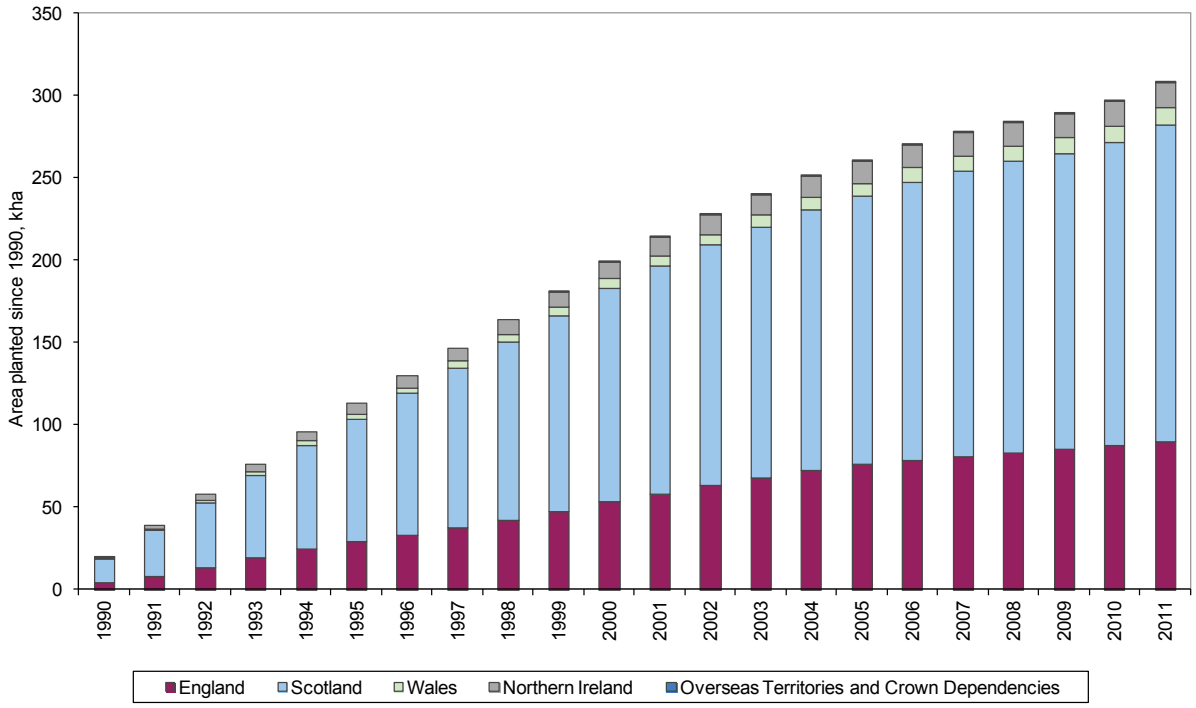


Figure 11-4 Area deforested since 1990 in the countries of the United Kingdom (note different scale from previous figure; no deforestation occurs in the OTs and CDs)

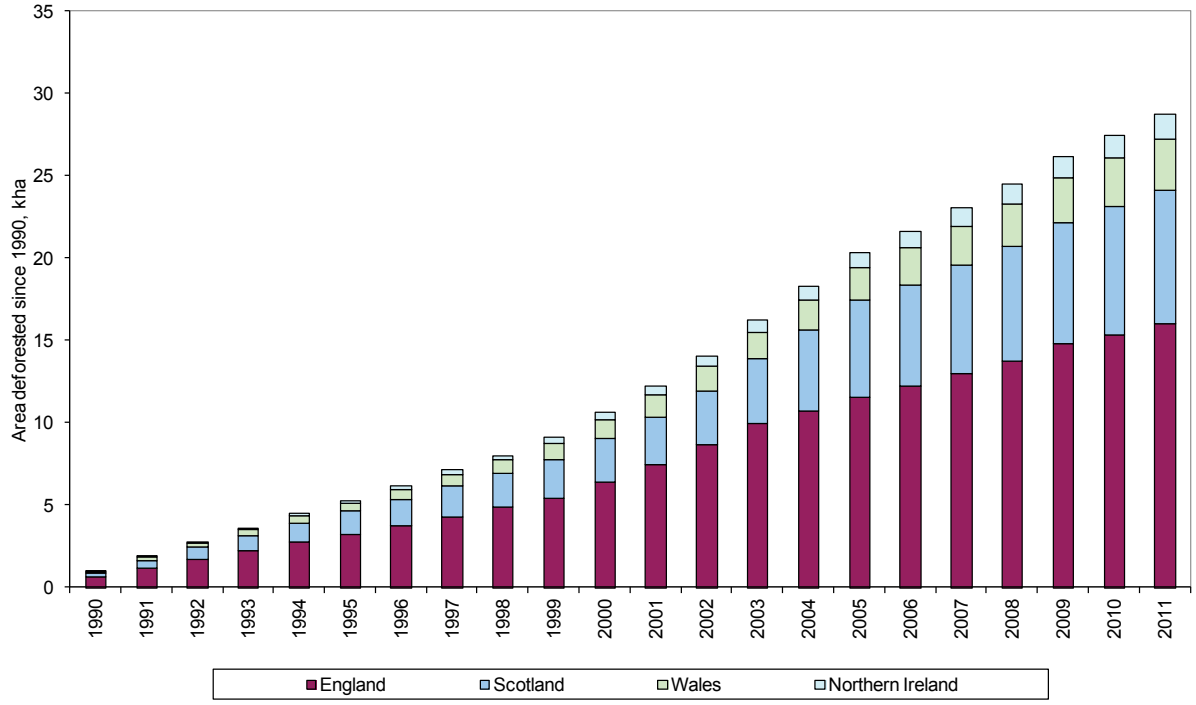


Figure 11-5 Area of Forest Management land 1990-2009 in the countries, Overseas Territories and Crown Dependencies of the United Kingdom

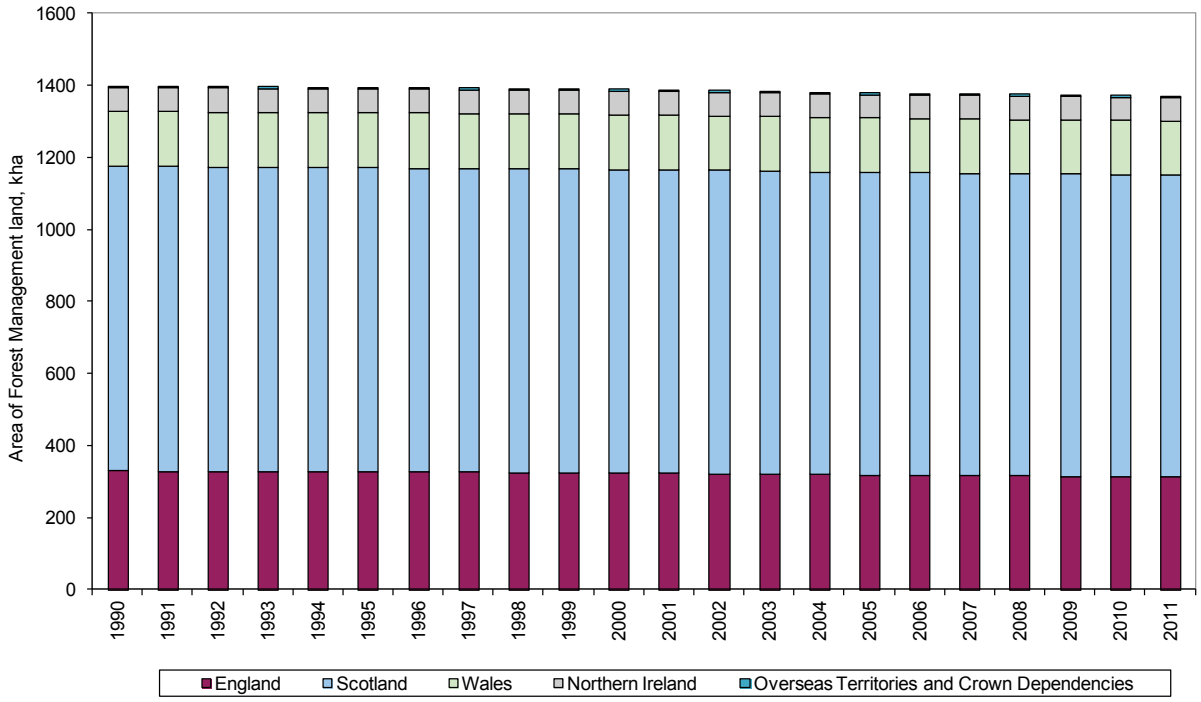


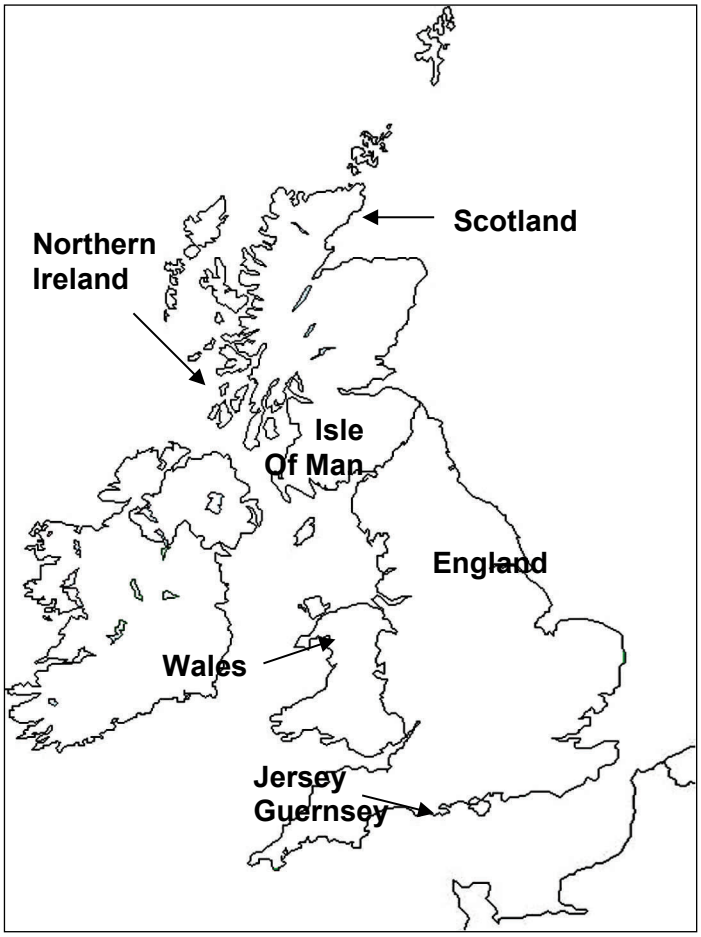
Table 11-2 Data sources on ARD and FM activities

Activity	Dataset	Available scale	Time period	Details
AR & FM	Annual planting statistics	Country	1921-present	New planting on previously non-forested land. Updated annually. Categorized into conifer and broadleaved woodland.
D	Forestry Commission Unconditional Felling Licence data	England, Scotland, Wales	England: 1992-2010; Scotland: 1999-2010; Wales: 1996-2010	Unconditional Felling Licences are issued for felling without restocking. Used to estimate deforestation in rural areas (primarily for heathland restoration). Omits felling for development purposes, e.g. construction of wind turbines. Available at http://www.forestry.gov.uk/datadownload
D	Land Use Change Statistics (survey of land converted to developed uses)	England only	1990-2008 (updated in 2010)	Estimates of the conversion of forest to urban/developed land use. Based on Ordnance Survey map updates, identifying changes through aerial surveys and other reporting, expected to capture most changes within five years. English data is extrapolated to GB scale and to current reporting year.
D	Countryside Survey (CS) 1990, 1998, 2007	Country (England, Scotland, Wales, Northern Ireland)	1990-2007	Estimated areas of woodland converted to other land uses from CS data (1990, 1998, 2007). There are known issues with CS over-estimating the extent of woodland conversion compared with the extent estimated by the Forestry Commission. This is due to differences in woodland definitions, amongst other causes. However, the CS data can be used to estimate the relative split of woodland conversion between grassland, cropland and settlements, using other known data to 'discount' the CS areas. There is no non-CS data for Northern Ireland so the discount rates for England or Wales are used, depending on availability.

11.2.3 Maps and database to identify the geographical locations, and the system of identification codes for the geographical locations

The individual countries of the United Kingdom and the Overseas Territories and Crown Dependencies have been used as the geographical areas for reporting (Figure 11.6). The Forestry Commission and Forest Service maintain administrative systems that allow areas of land to be tracked within each country of the UK (sub-compartment databases for state forests and grant scheme data for other woodland).

Figure 11-6 Geographical areas used for reporting Kyoto protocol LULUCF activities



11.3 ACTIVITY-SPECIFIC INFORMATION

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

11.3.1.1 Description of the methodologies and the underlying assumptions used

Methods for estimating carbon stock changes in forests (for Article 3.3 Afforestation/Reforestation and Article 3.4 Forest Management) are the same as those used for the UNFCCC greenhouse gas inventory: details are given in Annex 3.7. A carbon accounting model, C-Flow, is used to estimate the net change in pools of carbon in living biomass, litter and soil in conifer and broadleaved forests. In the KP CRF tables changes in carbon stock are reported for: above-ground biomass (gains and losses), litter (net changes) and soils (net changes in mineral and organic soils). Carbon stock changes in below-ground biomass and dead wood are reported as Included Elsewhere: below-ground biomass is calculated as part of the above-ground biomass and dead wood is calculated as part of the litter pool.

Annual data on forest planting is provided by the Forestry Commission, at a higher precision than that published in the annual Forestry Statistics and with non-grant-aided planting

separated out. Information on state afforestation is stored in the Forestry Commission Sub-Compartment Database (SCDB): this is the stand management database for state-owned and managed forest, containing information on species, age, yield class and management. Non-state forest information comes from the grant schemes by which the government encourages planting and management of private woodland. These schemes cover almost all private woodland planting since 1995: there is a small amount of non-grant aided woodland (mostly in England) which is assumed to be broadleaved natural regeneration but we have no further information on the management or permanence of this area. Areas included are those for which new planting grants have been paid and the planting has actually been completed. The FC will not pay grants prior to the planting taking place so it is assumed the areas are therefore stocked.

Estimates for carbon stock changes as a result of Article 3.3 Deforestation use the same methods as the UNFCCC greenhouse gas inventory (Annex 3.7). During deforestation, 40% of the above-ground biomass and dead organic matter (litter and dead wood) is burnt and emissions of CO_2, CH_4 and N_2O are reported in Table 5(KP-II)5. The remaining carbon stocks in biomass and dead organic matter (DOM) is assumed to be immediately lost. This loss (in Gg C) is calculated as:

Stock change = C fraction * % of biomass and DOM removed * (area * available biomass) * 0.001

where

carbon fraction = 0.5
proportion of biomass removed = 60%
area = area deforested, ha
available biomass = country-specific biomass and DOM densities

Carbon stock changes in soils as a result of deforestation are calculated using the dynamic model of carbon stock change discussed in Annex 3.7. It is not possible to report changes in mineral and organic soils separately since there are no separate activity data. Estimates of deforestation are now made for all countries of the UK.

Carbon stock changes due to Forest Management are estimated using the C-Flow model, as described in **Annex 3.7**. It is assumed that all deforestation occurs on Forest Management land, so the area of FM land and carbon stock changes are adjusted to reflect deforestation losses. This was done by running the model with the initial FM land area and calculating the implied carbon stock changes per unit area (as in the CRF tables). The Forest Management land areas were then adjusted to take account of annual deforestation (Figure 11.5), and the resulting areas multiplied by the implied carbon stock changes per unit area to give total carbon stock changes.

Greenhouse gas emissions (rather than carbon stock changes) from LULUCF activities under the Kyoto Protocol are reported in Tables 5(KP-II)1-5.

Table 5(KP-II)1. Direct N_2O emissions from N fertilization

The method used to estimate emissions is the same as that used in the UNFCCC greenhouse gas inventory and described in **Annex 3.7**. It is assumed that nitrogen fertilizer is only applied to newly planted forests in the UK (see **Chapter 7** for more information).

Table 5(KP-II)2. N_2O emissions from drainage of soils

Emissions of N_2O emissions from forest drainage are reported for the first time in this inventory. This also led to a re-assessment of the areas of forest planting on mineral and organic soils, affecting soil carbon stock changes. A detailed description of the new methodology and activity data is given in Annex 3.7.

Table 5(KP-II)3. N_2O emissions from disturbance associated with land use conversion to cropland.

Deforestation to Cropland in the UK since 1990 has been assessed using activity data from the latest Countryside Survey and Tier 1 methodology. Estimates of N_2O emissions from disturbance associated with forest conversion to Cropland are included in the inventory. Such land use conversions only occur in England, as the very small areas of conversion in the other countries of the UK are assessed as being due to survey classification errors rather than genuine land use change.

Table 5(KP-II)4. Carbon emissions from lime application

No lime is applied to existing and newly planted UK forests (Forestry Commission, pers. comm.). It is difficult and economically unviable to apply lime at the heavy rates required (Taylor 1991). It is assumed that land deforested to cropland will undergo some liming (in the same proportion and application rates as other cropland as described in Annex 3.7), although the areas involved are very small (<0.03 kha/year).

Table 5(KP-II)5. GHG emissions from biomass burning

The method used to estimate emissions is the same as that used in the UNFCCC greenhouse gas inventory and described in Annex 3.7. There is no information on the location of wildfires in forests in the UK, so wildfire emissions have been split between Afforestation/Reforestation land and Forest Management land on the basis of their proportion of the whole forest area (a ratio of 22:78 for the UK). As described above, it is assumed that 40% of the standing biomass and DOM undergoes controlled burning during deforestation and emissions from that burning are reported in this table. It is assumed that wildfires that cause deforestation do not occur in the UK, as there is a general commitment to maintaining forest area. However, it is possible for previously deforested land to undergo wildfire (for example on restored heathland). The new wildfire activity data is spatially explicit, so it was possible to assess whether there was any co-location of deforested areas (from the unconditional felling licence dataset) and wildfires. There was a single occurrence (57 ha) of a wildfire on previously deforested land in England in 2010, and estimated emissions from this event are now included in Table 5(KP-II)5.

11.3.1.2 Justification for omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

Table 5(KP-I)A.1.2 Article 3.3 activities: Afforestation and Reforestation. Units of land harvested since the beginning of the commitment period

It is assumed that no areas that have been afforested since 1990 have been harvested in the period 1990-2011, so carbon stock changes in this table are reported as NO (not occurring). There is an assumption that the species planted are managed so that they reach maturity (40 years or more) before harvesting.

Table 5(KP-I)A.1.3 Article 3.3 activities: Afforestation and Reforestation. Units of land otherwise subject to elected activities under Article 3.4 (information item)

Only Forest Management has been elected under Article 3.4. Any post-1921 forest land that is not reported under Article 3.3 is otherwise reported under Article 3.4 Forest Management.

Table 5(KP-I)A.2.1 Article 3.3 activities: Deforestation. Units of land otherwise subject to elected activities under Article 3.4 (information item)

Only Forest Management has been elected under Article 3.4. As Deforestation is a permanent loss of forest cover, any unit of land that has been deforested under Article 3.3 has previously been subject to Forest Management under Article 3.4.

Table 5(KP-II)1. Direct N_2O emissions from N fertilization

It is assumed that nitrogen is only applied to newly planted forests in the UK, therefore no N fertilization occurs on Forest Management land. It is assumed that no areas that have been afforested since 1990 have been harvested in the period 1990-2010 so emissions for A.1.2 are reported as Not Occurring.

Table 5(KP-II)3. N_2O emissions from disturbance associated with land use conversion to cropland.

Such land use conversions only occur in England, as the very small areas of conversion in the other countries of the UK are assessed as being due to survey classification errors rather than genuine land use change and are reported as NO.

Table 5(KP-II)4. Carbon emissions from lime application

No lime is applied to established or newly planted UK forests (Forestry Commission, pers. comm.), so emissions are reported as Not Occurring for Afforestation/Reforestation and Forest Management areas. Some liming application occurs on land deforested to Cropland but only in England (see above).

Table 5(KP-II)5. GHG emissions from biomass burning

There is no controlled burning for management in UK forests, so this is reported as Not Occurring under Afforestation/Reforestation and Forest Management. No forest wildfires were reported in Northern Ireland in 2010 (although they had occurred in other years). Wildfires on deforested land will be reported when they occur (as has happened in 2010) but they are infrequent, so otherwise they will be reported as Not Occurring.

11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

The UK inventory approach to estimating forest carbon stock changes is based on modelled growth data rather than national-scale measurements of forest annual volume increments. The CFlow model is based on yield class tables, and in principle assumes constant weather and management conditions. Therefore 'factoring out' of climate change effects is not required. Work has been undertaken to model the impact of climate, CO_2 and land use change on the carbon balance of terrestrial ecosystems in Great Britain (Levy and Clark 2009) and interaction between these factors. This suggested that interactions are small and the effects of these environmental factors are additive. Nitrogen dynamics were not considered in this work: the extent to which enhanced nitrogen deposition affects forest carbon sequestration remains contentious (Magnani *et al* 2007; Sutton *et al* 2008). Much of the United Kingdom's forest area was established during the 20th century, and forests are still in their first or second rotation. The dynamic effects of the age structure are taken into account in Art 3.3 and Article 3.4 Forest Management, the latter being limited by the FM cap.

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

This is the fourth official submission of Article 3.3 and Article 3.4 estimates, and some recalculations have been made since the previous submission (**Table 11-3**).

Table 11-3 KP-LULUCF recalculations to activity data since previous submission

IPCC Category	Source Name	2012 submission 2010	2013 submission 2010	Units	Comment/Justification
KP.A.1.1	Carbon stock change /Above-ground biomass	718.22	718.23	Gg C	Reporting of Afforestation in the Overseas Territories and Crown Dependencies for the first time
KP.A.1.1	Carbon stock change/Litter	26.78	26.78	Gg C	Reporting of Afforestation in the Overseas Territories and Crown Dependencies for the first time
KP.A.1.1	Carbon stock change in soils/Mineral	55.55	55.32	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage. Reporting of Afforestation in the Overseas Territories and Crown Dependencies for the first time
KP.A.1.1	Carbon stock change in soils/Organic	12.04	12.11	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
KP.A.1.1	5(KP-II)1 Direct N_2O emissions from N fertilisation	0.00	0.00	Gg N_2O	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
KP.A.1.1	5(KP-II)5 Biomass burning/Wildfires	20.26	5.53	Gg CO_2	Revised activity data on wildfires and inclusion of DOM in biomass burning
KP.A.1.1	5(KP-II)5 Biomass burning/Wildfires	0.09	0.02	Gg CH_4	Revised activity data on wildfires and inclusion of DOM in biomass burning
KP.A.1.1	5(KP-II)5 Biomass burning/Wildfires	0.00	0.00	Gg N_2O	Revised activity data on wildfires and inclusion of DOM in biomass burning
KP.A.2	Carbon stock change/Above-ground biomass	-101.35	-67.13	Gg C	Biomass losses and DOM are now estimated from country-specific biomass densities
KP.A.2	Carbon stock change/Litter	IE	-8.21	Gg C	Biomass losses and DOM are now estimated from country-specific biomass densities
KP.A.2	Carbon stock change in soils/Mineral	-31.59	-25.47	Gg C	Adjustment of time series in activity data
KP.A.2	5(KP-II)3 N_2O emissions from disturbance associated with LUC to cropland	0.00	0.00	Gg N_2O	Minor adjustment of activity data (emissions from land use change more than 20 years ago not included)
KP.A.2	5(KP-II)4 Carbon emissions from lime application	0.01	0.01	Gg C	Adjustment of grass/cropland split for liming
KP.A.2	5(KP-II)5 Biomass burning/Controlled burning	222.97	165.76	Gg CO_2	Revision of biomass densities used to estimate biomass burnt and inclusion of DOM in estimates for first time

IPCC Category	Source Name	2012 submission 2010	2013 submission 2010	Units	Comment/Justification
KP.A.2	5(KP-II)5 Biomass burning/Controlled burning	0.97	0.72	Gg CH_4	Revision of biomass densities used to estimate biomass burnt and inclusion of DOM in estimates for first time
KP.A.2	5(KP-II)5 Biomass burning/Controlled burning	0.01	0.00	Gg N_2O	Revision of biomass densities used to estimate biomass burnt and inclusion of DOM in estimates for first time
KP.A.2	5(KP-II)5 Biomass burning/Wildfires	NE	1.06	Gg CO_2	New activity data for wildfires on deforested land
KP.A.2	5(KP-II)5 Biomass burning/Wildfires	NE	0.00	Gg CH_4	New activity data for wildfires on deforested land
KP.A.2	5(KP-II)5 Biomass burning/Wildfires	NE	0.00	Gg N_2O	New activity data for wildfires on deforested land
KP.B.1	Carbon stock change/Above-ground biomass	621.87	629.80	Gg C	Revision of biomass densities used to estimate biomass burnt and inclusion of DOM in estimates for first time. Reporting of Forest Management in the Overseas Territories and Crown Dependencies for the first time
KP.B.1	Carbon stock change/Litter	673.94	674.34	Gg C	Revision of biomass densities used to estimate biomass burnt and inclusion of DOM in estimates for first time. Reporting of Forest Management in the Overseas Territories and Crown Dependencies for the first time
KP.B.1	Carbon stock change in soils/Mineral	632.54	640.03	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage. Reporting of Forest Management in the Overseas Territories and Crown Dependencies for the first time
KP.B.1	Carbon stock change in soils/Organic	135.23	127.89	Gg C	Adjustment of area split between forest planting on mineral and organic soil due to new data on drainage
KP.B.1	5(KP-II)2 N_2O emissions from drainage	NE	0.12	Gg N_2O	Reporting of emissions from forest drainage for the first time
KP.B.1	5(KP-II)5 Biomass burning/Wildfires	68.94	61.41	Gg CO_2	Revision of biomass densities used to estimate biomass burnt and inclusion of DOM in estimates for first time
KP.B.1	5(KP-II)5 Biomass burning/Wildfires	0.30	0.21	Gg CH_4	Revision of biomass densities used to estimate biomass burnt and inclusion of DOM in estimates for first time
KP.B.1	5(KP-II)5 Biomass burning/Wildfires	0.00	0.01	Gg N_2O	Revision of biomass densities used to estimate biomass burnt and inclusion of DOM in estimates for first time

11.3.1.5 Uncertainty estimates

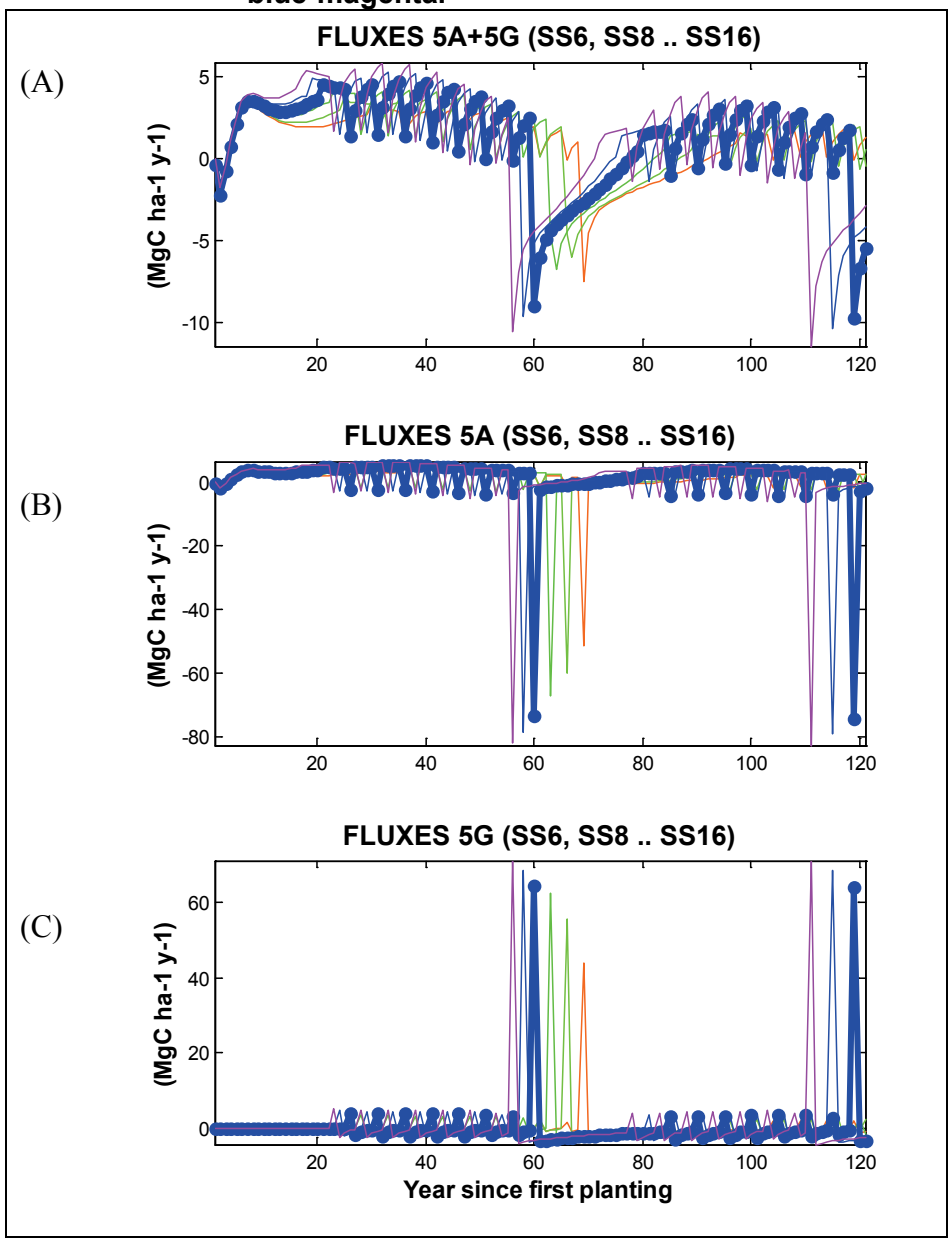
Uncertainty assessment and quantification of the inventory has been undertaken during 2007-2009, with particular focus on the forest carbon modelling components (van Oijen 2007; 2008; 2009; van Oijen and Thomson 2010). The carbon flow model, CFlow (Dewar and Cannell 1992), is used to model carbon pools and fluxes in UK forests (described in Annex 3.7). The uncertainty arising from the inputs, parameters and model structure of CFlow has been examined, and it has also been compared with a more complex process-based model, BASFOR (van Oijen and Thomson, 2010). This work is described in the 1990-2008 national inventory report.

Uncertainty from model inputs.

The IPCC Tier 2 approach for uncertainty quantification recommends quantifying the uncertainties associated with individual input factors by expressing them as probability distribution functions (PDFs). Sampling from the PDFs propagates input uncertainty through the model to the outputs. However, 'knowledge about parameters is generally incomplete; they interact and uncertainty may propagate non-linearly in the calculations. If the only source of information utilized for the PDFs is direct measurement or expert opinion, the resulting output may be overly high' (van Oijen and Thomson, 2010). Bayesian techniques (van Oijen *et al*. 2005, Patenaude *et al*, 2008) have been used in this uncertainty assessment to reduce input uncertainties where possible.

CFlow requires input data on the afforestation rate (ha yr^{-1}) and yield class (mean wood volume production, m^3 ha^{-1} yr^{-1}) for different forest types and regions in the UK. CFlow has near-linearity with respect to the yield class input, i.e. the use of yield class 12 m^3 ha^{-1} yr^{-1} for conifers (used in CFlow) produces a carbon flux time series that closely approximates the mean of yield classes 8,10,12,14 and 16 m^3 ha^{-1} yr^{-1} (van Oijen 2008). The average annual flux over 100 years since first planting for yield class 12 is 1.53 Mg C ha^{-1} yr^{-1} (biomass+litter+soil), with values for other yield classes ranging from 1.18 Mg C ha^{-1} yr^{-1} (-23%, yield class 8) to 1.97 Mg C ha^{-1} yr^{-1} (+29%, yield class 16). However, very large uncertainties can arise when assessing carbon sequestration for specific calendar years with different yield classes as harvesting produces a large flux (**Figure 11-7** B and C). However, when categories 5A and 5G (Forest Land and Harvested Wood Products) are considered together the combined uncertainty is much smaller (**Figure 11-7** A) because of the opposite effect that harvesting has on these two stock pools. It should also be noted that these graphs show the fluxes from a single instance of planting: when spatio-temporal patterns across the UK are combined together these inter-year uncertainties are cancelled out to a large extent.

Figure 11-7 **Comparison of flux time series since first planting from CFlow for Sitka spruce yield class 6,8…16. The default curve (YC12) is shown in bold blue. Lower yield classes are in red-green, higher yield classes in blue-magenta.**



No measures of statistical uncertainty are associated with the planting statistics because they come from administrative systems (assumed to have total coverage) rather than surveys (Forestry Commission, pers. comm.).

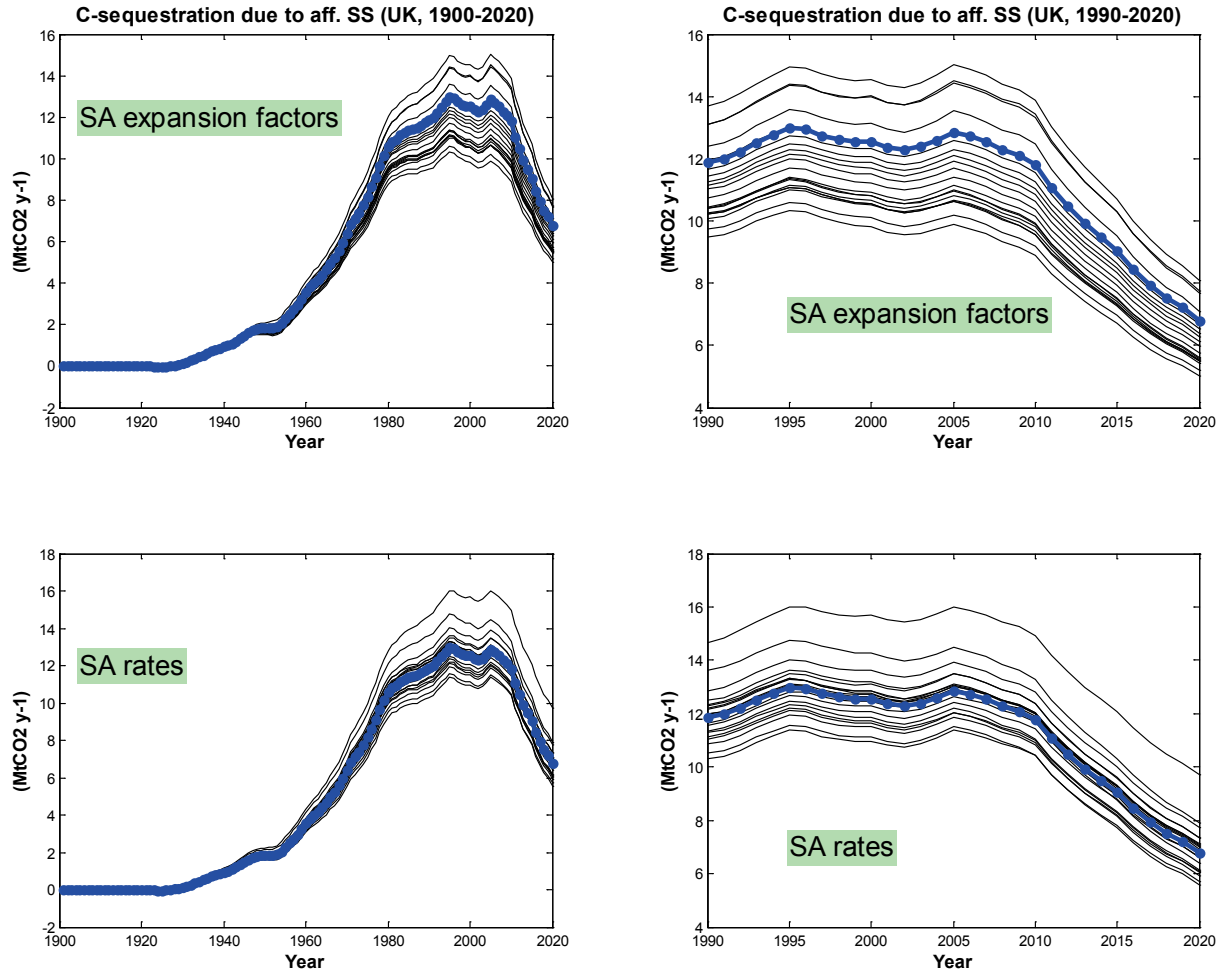
Uncertainty from model parameters

Dewar and Cannell (1992) include a sensitivity analysis of CFlow's parameters. The processes and parameters that were most uncertain or variable were: the fractions of woody biomass in branches and woody roots, litter and soil organic matter decomposition rates and the rate of fine root turnover. Other parameters were known to reasonable accuracy and/or had a small impact on carbon storage.

Additional sensitivity analysis was presented in van Oijen (2009). The sensitivity of the biomass expansion factor and turnover rate parameters (controlling the carbon partitioning between trees, litter and soil) were modelled with 30% uncertainty about the default parameters under a uniform distribution (**Figure 11-8**). Changes in parameters do not affect the overall time pattern of carbon sequestration due to afforestation. Of particular relevance to Kyoto Protocol reporting is that there are only minor differences between sink strength in any given year and a reference year, e.g. 1990.

Top row: changes in expansion factors. Bottom row: changes in turnover rates. Blue lines: default parameterisation. Black lines: sample of 20 parameter vectors from a multivariate uniform distribution where every individual parameter has a range from 0.7 to 1.3 times its default.

Figure 11-8 Sensitivity analysis (SA) of 5A+5G to changes in parameters.



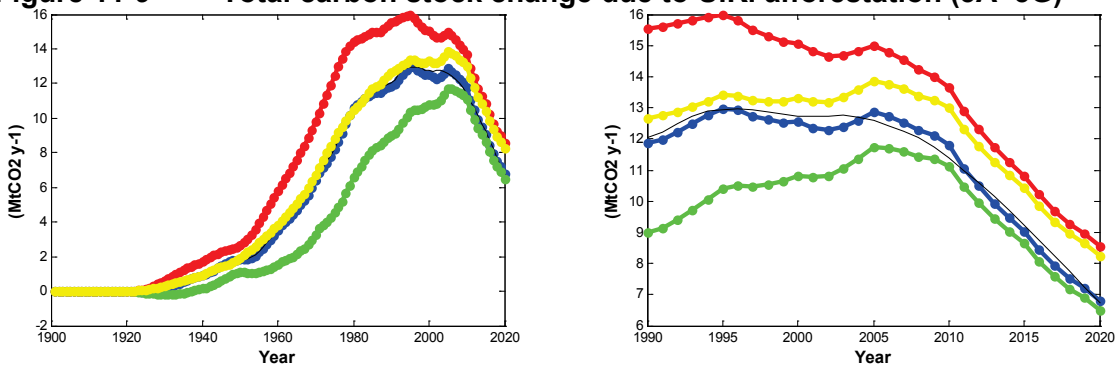
Note: Top row: changes in expansion factors. Bottom row: changes in turnover rates. Blue lines: default parameterisation. Black lines: sample of 20 parameter vectors from a multivariate uniform distribution where every individual parameter has a range from 0.7 to 1.3 times its default.

Uncertainty from model structure

Van Oijen (2009) also examined the inclusion of certain processes within CFlow: the gradual loss of pre-existing soil carbon due to planting disturbance and carbon removal by ground vegetation before canopy closure (based on Hargreaves *et al*. 2003). The assumptions regarding the dynamics of these processes do not affect the general pattern of carbon stock

change over time but do affect the magnitude of that stock change (**Figure 11-9**). The implementation of both processes was based on a limited amount of empirical information, so the reliability of the current model is to some extent uncertain. However, the existence of these processes is not in doubt- their magnitude and change over time are (so the graphs over-estimate the uncertainty regarding these processes).

Figure 11-9 Total carbon stock change due to U.K. afforestation (5A+5G)



Left: 1900-2020, right: 1990-2020. Blue line: actual inventory method. Red: no emissions from pre-existing soil carbon. Green: no removal by grass growth. Yellow: neither process (i.e. "Red+Green").

Work using a more complex process-based carbon flow model (BasFor) discovered that uncertainties showed distinct spatial trends across the UK, as a result of heterogeneous environmental conditions (van Oijen and Thomson 2010). This suggests that a simple approach to forestry-related uncertainty (i.e. assuming uncertainty to be a fixed percentage of the absolute flux rate) is not applicable.

This work has not yet produced a simple uncertainty estimate for reporting, so work is continuing in this area. In the interim, an uncertainty of 25% for Article 3.3 Afforestation/Reforestation and Article 3.4 will be used (as estimated for UNFCCC category 5A) and an uncertainty of 50% for Article 3.3 Deforestation (based on expert judgement).

11.3.1.6 Information on other methodological issues

Disturbances. Data is available on fire damage to state-managed forests and extrapolated to privately-managed forests (see **Chapter 7** and **Annex 3.7** for further details). There is no data available on the type of forest burnt by wildfires (species or age). Wildfire locations within each country of the UK are only available for 2009 onwards (See Annex 3.7). Wildfires are not assumed to result in a permanent change in land use. Damage from windblow is not reported in the UNFCCC inventory, although it does occur in the UK (FAO, 2010; Forestry Commission, 2002). There are currently insufficient data to include the effects of these disturbances in the inventory. If a storm causing extensive, widespread forest destruction occurred (as in the 1987 storm in southern England) then this would be taken account of on an *ad hoc* basis.

Inter-annual variability. The method used to estimate emissions and removals from AR and FM is based on the C-Flow model. This model is not sensitive to inter-annual variation in environmental conditions so these will not affect the annual growth and decay rates. There is an ongoing research project to look at the variation in management conditions across the UK forest estate and over time. The area burnt in wildfires does show inter-annual variation and this is included in the emissions methodology.

11.3.1.7 The year of the onset of an activity, if after 2008

5 361 ha of land were afforested in 2009, 7 424 ha in 2010 and 11 569 ha in 2011. 1 655 ha of land were deforested in 2009, 1 289 ha in 2010 and 1 255 ha in 2011.

11.4 ARTICLE 3.3

11.4.1 Information that demonstrates that activities began on or after 1 January 1990 and before 31 December 2012 and are directly human-induced

Under the current methodology, the Forestry Commission and the Forest Service of Northern Ireland provide annual data on new planting (on land that has not previously been forested). This information is provided for each country in the UK and the time series extends back before 1990. Data are provided by 'financial' year and then adjusted to calendar years as described in **Section 11.1.3**. Information on new planting and restocking are published as separate figures for both state and private woodlands. New planting can use planting/seeding or natural colonisation. Data come from administrative systems (state forests) and grant schemes (other woodland) (Forestry Statistics 2011). Areas of planting that are not state-owned or grant-aided (i.e. whether these woodlands are explicitly managed is unknown) are not included in the GHGI or Article 3.3 AR.

Information on deforestation is assembled from felling licences for deforestation to other rural land uses and information on the conversion of forests to settlement land uses, both of which can thereby be shown to be directly human-induced. The time series of activity data is not sufficiently detailed to demonstrate the exact date of deforestation within a year at present.

11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

The data sources used for estimating Deforestation do not allow for confusion between harvesting or forest disturbance and deforestation. This is because the unconditional felling licences used for the estimation of rural deforestation are only given when no restocking will occur, and the survey of land converted to developed use describes the conversion of forest land to the settlement category, which precludes re-establishment. The Countryside Survey data (used for gap filling) is adjusted in order that deforestation is not over-estimated. A new national forest inventory will be partially completed by the end of the commitment period and will be used to verify deforestation estimates made using these data sources.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforested

Restocking is assumed for forest areas that have lost forest cover through harvesting or forest disturbance, unless there is deforestation as described above. Information on the size and location of forest areas that have lost forest cover is not explicitly collected on an annual basis. The area of felled forest awaiting restocking was reported in the National Inventory of Woodland and Trees in the mid-late 1990s: this was 1.4% of the total forest area in England (15,100 ha), 1.8% in Scotland (22,979 ha) and 3.1% in Wales (8,961 ha) (Forestry Commission 2002). A comparable inventory was not available for Northern Ireland but in

2002 410 ha of Forest Service land was awaiting replanting (0.5% of the state forest area) (Forest Service 2002).

11.5 ARTICLE 3.4

11.5.1 Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

All managed forests (planted between 1921 and 1989) are included in Article 3.4 Forest Management because forest management is an on-going activity. The C-Flow model is used to calculate emissions from this forest area after 1990 that have arisen from thinning, harvesting and restocking. The area under Forest Management is adjusted to reflect losses from deforestation, as recorded in **Section 11.1.3**.

11.5.2 Information relating to Cropland Management, Grazing Land Management and Revegetation, if elected, for the base year

These activities were not elected by the United Kingdom.

11.5.3 Information relating to Forest Management

11.5.3.1 That the definition of forest for this category conforms with the definition in item 11.1 above

Data used for estimating emissions from Forest Management is supplied by the Forestry Commission and complies with their definition of forest land, which is the one used for Article 3.3 and 3.4 activities (**Section 11.1.1**).

11.5.3.2 That forest management is a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner.

The UK has a system of certification for sustainable woodland management under the Forest Stewardship Council (FSC) (http://www.fsc-uk.org/). As of March 2012, 1365 kha of woodland in the UK (44%) was certified under the FSC scheme (Forestry Statistics 2012). The management practices in certified woodlands are reviewed on a regular basis (3-5 years). All state-owned forests are certified and an increasing proportion of non-state-owned woodlands are becoming certified (36% in 2012). This does not include all woodland that is managed in a sustainable manner, such as smaller or non-timber producing woodlands where certification is not considered worthwhile. In particular, it may omit many broadleaved woodlands even though they are managed for their social and environmental benefits (Forestry Commission, 2002). In the UK's country report to the Global Forest Resource Assessment 2010 (FAO, 2010) 83% of UK forests are managed for production and 18% are managed for conservation of biodiversity (these have protected status). Only 4% have a primary social services (public access) function, but 55% are listed as having multiple uses, many of which will include social functions.

11.6 OTHER INFORMATION

11.6.1 Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

Three categories are considered to be key: Article 3.3 Afforestation and Reforestation (CO_2), Article 3.3 Deforestation (CO_2) and Article 3.4 Forest Management (CO_2). These have been assessed according to the IPCC good practice guidance for LULUCF **Section 5.4.4**. The numbers have been compared with Table A 1.1.5 Key category analysis for the latest reported year (2011) based on level of emissions (including LULUCF).

Article 3.3 Afforestation and Reforestation (CO_2): The associated UNFCCC category 5A (-10 222 Gg CO_2) is a key category although the AR component (forest planted since 1990) is not key on its own (i.e. its category contribution (-3 062 Gg CO_2) is smaller than the smallest UNFCCC key category (1A Coal)). Removals from this category are also predicted to increase over time as a result of tree planting schemes partially focussed on climate change mitigation.

Article 3.3 Deforestation (CO_2): The associated UNFCCC categories (5B, 5C and 5E) are key categories (11 454, -8 484 and 6 320 Gg CO_2 respectively). However, the Deforestation category contribution (536 Gg CO_2) to these UNFCCC categories is smaller than the smallest UNFCCC key category (1A Coal). The data used in the calculation of deforestation emissions are the most uncertain of the data sources in the KP-LULUCF inventory and are a priority for improvement.

Article 3.4 Forest Management (CO_2): The associated UNFCCC category 5A is a key category (-10 222Gg CO_2). The Forest Management category contribution (-7 268 Gg CO_2) is also greater than other categories in the UNFCCC key category.

These categories are the priority for improvement in the KP-LULUCF inventory, and there is ongoing development (described in **Chapter 7**).

11.6.2 Information relating to Article 6

Not applicable in the United Kingdom.

12 Information on accounting of Kyoto units

12.1 BACKGROUND INFORMATION

The UK's Standard Electronic Format report for 2012 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF has been submitted to the UNFCCC Secretariat electronically – SEF_GB_2013_1_14-51-34 11-4-2013.xls.

12.2 SUMMARY OF INFORMATION REPORTED IN THE SEF TABLES

At the end of 2012, there were 17,310 AAUs in the UK registry of which 2,829,669,817 were in the party holding account, 17,310 in the entity holding account, 36,687 in other cancellation accounts and 922,284658 in the retirement account. The registry also contained a total of 64,755,068 CERs and 88,595,920 ERUs.

In total for 2012, the UK Registry received 12,4274,211 AAUs, 274,776,953 ERUs, 255,741,856 CERs and 4,250,000 RMUs. Conversely, 150,232,806 AAUs, 195,512,568 ERUs, 265,570,444 CERs and 4,250,000 RMUs were externally transferred to other national registries. Account holders voluntarily cancelled 36,687 AAUs and 1,869,841 CERS. There were no transactions of any kind involving ERUs, RMUs, tCERs or lCERs.

During 2012, 204,599,858 AAUs, 1,339,217 ERUs and 14,631,731 CERs were retired.

Full details are available in the SEF tables; the full tables are shown in Annex 6.

Information on legal entities authorised to participate in mechanisms under Articles 6, 12 and 17 of the Kyoto Protocol can be found on the Emissions Registry website in the reports area at http://emissionsregistry.environment-agency.gov.uk/ .

Table 12-1 Details on Standard electronic format

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E paragraph 11: Standard electronic format (SEF)	UK's Standard Electronic Format report for 2012 containing the information required in paragraph 11 of the annex to decision 15/CMP.1 and adhering to the guidelines of the SEF has been submitted to the NFCCC Secretariat electronically. SEF_GB_2013_1_14-51-34 11-4-2013.xls The contents of the SEF report (R1) can also be found in Annex 6 of this document.

12.3 DISCREPANCIES AND NOTIFICATIONS

Information regarding discrepancies and notifications is summarised in **Table 12-2.**

Table 12-2 Summary of discrepancies and notifications

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E paragraph 12: List of discrepant transactions	The list of discrepant transactions is listed in the table named "R2" in the SIAR Excel file.
15/CMP.1 annex I.E paragraph 13 & 14: List of CDM notifications	No CDM notifications occurred in 2012. Refer to SIAR Excel file, Worksheet R3.
15/CMP.1 annex I.E paragraph 15: List of non-replacements	No non-replacements occurred in 2012. Refer to SIAR Excel file, Worksheet R4.
15/CMP.1 annex I.E paragraph 16: List of invalid units	No invalid units exist as at 31 December 2012. Refer to SIAR Excel file, Worksheet R5.
15/CMP.1 annex I.E paragraph 17 Actions and changes to address discrepancies	Actions and changes are addressed in Chapter 14: Information on Changes to National Register under section Change of discrepancies procedures.

12.4 PUBLICLY ACCESSIBLE INFORMATION

Information on legal entities authorised to participate in mechanisms under Articles 6, 12 and 17 of the Kyoto Protocol can be found on the Emissions registry website at http://emissionsregistry.environment-agency.gov.uk/. Further details are summarised in **Table 12-3** below.

Table 12-3 Details of publicly accessible information

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E Publicly accessible information	The following information is now deemed publicly accessible and as such is available via the homepage of the UK registry – http://emissionsregistry.environment-agency.gov.uk/. 2 links (UNFCCC Public Reports and European Commission Public Reports), are available on this site with direct access to the reports. In accordance with the requirements of Annex E to Decision 13/CMP.1, all required information for a Party with an active Kyoto registry is provided with the exceptions as outlined below.

Annual Submission Item	Reporting Guidance
	Account Information (Paragraph 45) Article 78 of the Registry Regulation that came into force in August 2010 requires that representative identification information is held as confidential. Account holders authorised to hold Kyoto units in their account (Paragraph 48) Article 78 of the Registry Regulation that came into force in August 2010 requires that representative identification information is held as confidential. JI projects in UK (Paragraph 46) Note that no Article 6 (Joint Implementation) project is reported as conversion to an ERU under an Article 6 project, as this did not occur in the specified period. The United Kingdom has taken the decision not to host any domestic JI projects, clarification of which is on our registry public pages http://emissionsregistry.environment-agency.gov.uk/ Paragraph 47 a/d/f - Holding and transaction information of units Holding and transaction information is provided on a holding type level, due to more detailed information being declared confidential by EU Regulation. Article 10 of EU Regulation 2216/2004/EC, provides that "All information, including the holdings of all accounts and all transactions made, held in the registries and the Community independent transaction log shall be considered confidential for any purpose other than the implementation of the requirements of this Regulation, Directive 2003/87/EC or national law." Paragraph 47c The United Kingdom is not hosting domestic JI projects as per paragraph 46 above.
	Paragraph 47e The United Kingdom is currently not participating in any LULUCF projects for 2012. Paragraph 47g No ERUs, CERs, AAUs and RMUs have been cancelled on the basis of activities under Article 3, paragraphs 3 and 4 to date. Paragraph 47h No ERUs, CERs, AAUs and RMUs have been cancelled following determination by the Compliance Committee that the Party is not in compliance with its commitment under Article 3, paragraph 1 to date. Paragraph 47j No ERUs, CERs, AAUs nor RMUs have been retired to date. Paragraph 47k There is no previous commitment period to carry ERUs, CERs, and AAUs over from.

12.5 CALCULATION OF THE COMMITMENT PERIOD RESERVE (CPR)

Annual Submission Item	Reporting Guidance
15/CMP.1 annex I.E paragraph 18 CPR Calculation	The Annex to Decision 11/CMP.1 (paragraph 6) specifies that: '*each Party included in Annex I shall maintain, in its national registry, a commitment period reserve which should not drop below 90 per cent of the Party's assigned amount calculated pursuant to Article 3, paragraphs 7 and 8 of the Kyoto Protocol, or 100 per cent of five times its most recently reviewed inventory,* ***whichever is lowest***'. Therefore the **UK's commitment period reserve** is calculated as the lower of: Either 90% of the UK's assigned amount – see above = 0.9 x 3,412,080,630 tonnes CO_2 equivalent = 3,070,872,567 tonnes CO_2 equivalent. or 100% of 5 x most recently reviewed inventory (2009) = 5 x 572,151,151 tonnes CO_2 equivalent = 2,860,755,755 tonnes CO_2 equivalent The lower of the two numbers is that calculated as 100 per cent of 5 x the most recently reviewed inventory. The UK's Commitment Period Reserve is therefore **2,860,755,755 tonnes of CO_2 equivalent (or assigned amount units)**. The 1990-2009 inventory has been taken as the most recently reviewed inventory, because the report of the 1990-2010 inventory review is not yet finalised.

12.6 KP-LULUCF ACCOUNTING

The UK intends to account for Article 3.3 and 3.4 LULUCF activities for the entire commitment period, rather than annually. This is because the periodic nature of survey data means that a more detailed and accurate assessment, based on the best possible information, will be possible at the end of the first commitment period.

13 Information on changes in national system

13.1 CHANGES TO THE NATIONAL SYSTEM

The inventory agency was AEA Technology plc until November 2012. AEA Technology plc was acquired on the 8 November 2012 as a subsidiary of Ricardo plc and Ricardo-AEA Ltd. was formed. Ricardo-AEA Ltd. Is therefore now the inventory agency.

The inventory is managed by Ricardo-AEA under contract to the Science Division the UK Department of Energy and Climate Change (DECC). The Science Division was previously known as the Climate, Energy, Science and Analysis Division.

These changes have not affected the management of the National System or the operation and delivery of the inventory, and key roles within the National Inventory System remain the same, as shown in **Table 1.3** in the Introduction.

14 Information on changes in the national registry

Directive 2009/29/EC adopted in 2009, provides for the centralization of the EU ETS operations into a single European Union registry operated by the European Commission as well as for the inclusion of the aviation sector. At the same time, and with a view to increasing efficiency in the operations of their respective national registries, the EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway decided to operate their registries in a consolidated manner in accordance with all relevant decisions applicable to the establishment of Party registries - in particular Decision 13/CMP.1 and decision 24/CP.8.

With a view to complying with the new requirements of Commission Regulation 920/2010 and Commission Regulation 1193/2011, in addition to implementing the platform shared by the consolidating Parties, the registry of EU has undergone a major re-development. The consolidated platform which implements the national registries in a consolidated manner (including the registry of EU) is called Consolidated System of EU registries (CSEUR) and was developed together with the new EU registry on the basis the following modalities:

(1) Each Party retains its organization designated as its registry administrator to maintain the national registry of that Party and remains responsible for all the obligations of Parties that are to be fulfilled through registries;

(2) Each Kyoto unit issued by the Parties in such a consolidated system is issued by one of the constituent Parties and continues to carry the Party of origin identifier in its unique serial number;

(3) Each Party retains its own set of national accounts as required by paragraph 21 of the Annex to Decision 15/CMP.1. Each account within a national registry keeps a unique account number comprising the identifier of the Party and a unique number within the Party where the account is maintained;

(4) Kyoto transactions continue to be forwarded to and checked by the UNFCCC Independent Transaction Log (ITL), which remains responsible for verifying the accuracy and validity of those transactions;

(5) The transaction log and registries continue to reconcile their data with each other in order to ensure data consistency and facilitate the automated checks of the ITL;

(6) The requirements of paragraphs 44 to 48 of the Annex to Decision 13/CMP.1 concerning making non-confidential information accessible to the public would be fulfilled by each Party individually;

(7) All registries reside on a consolidated IT platform sharing the same infrastructure technologies. The chosen architecture implements modalities to ensure that the consolidated national registries are uniquely identifiable, protected and distinguishable from each other, notably:

(a) With regards to the data exchange, each national registry connects to the ITL directly and establishes a distinct and secure communication link through a consolidated communication channel (VPN tunnel);

(b) The ITL remains responsible for authenticating the national registries and takes the full and final record of all transactions involving Kyoto units and other administrative processes such that those actions cannot be disputed or repudiated;

(c) With regards to the data storage, the consolidated platform continues to guarantee that data is kept confidential and protected against unauthorized manipulation;

(d) The data storage architecture also ensures that the data pertaining to a national registry are distinguishable and uniquely identifiable from the data pertaining to other consolidated national registries;

(e) In addition, each consolidated national registry keeps a distinct user access entry point (URL) and a distinct set of authorisation and configuration rules.

Following the successful implementation of the CSEUR platform, the 28 national registries concerned were re-certified in June 2012 and switched over to their new national registry on 20 June 2012. During the go-live process, all relevant transaction and holdings data were migrated to the CSEUR platform and the individual connections to and from the ITL were re-established for each Party.

The following changes to the national registry of UK have therefore occurred in 2012, as a consequence of the transition to the CSEUR platform:

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change in the name or contact information of the registry administrator occurred during the reported period

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	The EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway have decided to operate their registries in a consolidated manner. The Consolidated System of EU registries was certified on 1 June 2012 and went to production on 20 June 2012. A complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. This description includes: • **Readiness questionnaire** • **Application logging** **Change management procedure** **Disaster recovery** • **Manual Intervention** • **Operational Plan** • **Roles and responsibilities** • **Security Plan** • **Time Validation Plan** • **Version change Management** The documents above are provided as an appendix to this document. A new central service desk was also set up to support the registry administrators of the consolidated system. The new service desk acts as 2nd level of support to the local support provided by the Parties. It also plays a key communication role with the ITL Service Desk with regards notably to connectivity or reconciliation issues.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	In 2012, the EU registry has undergone a major redevelopment with a view to comply with the new requirements of Commission Regulation 920/2010 and Commission Regulation 1193/2011 in addition to implementing the Consolidated System of EU registries (CSEUR). The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is annexed to this submission. During certification, the consolidated registry was notably subject to connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the Data Exchange Standard (DES). All tests were executed successfully and lead to **successful certification on 1 June2012.**
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	The overall change to a Consolidated System of EU Registries triggered changes the registry software and required new conformance testing. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is annexed to this submission. During certification, the consolidated registry was notably subject to connectivity testing, connectivity reliability testing, distinctness testing and interoperability testing to demonstrate capacity and conformance to the DES. All tests were executed successfully and lead to successful certification on 1 June 2012,

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	The overall change to a Consolidated System of EU Registries also triggered changes to discrepancies procedures, as reflected in the updated **manual intervention** document and **the operational plan**. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is annexed to this submission..
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	The overall change to a Consolidated System of EU Registries also triggered changes to security, as reflected in the updated **security plan**. The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is annexed to this submission.
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	Links to the publicly available information are found at the following link and information to be made public pursuant to part E of the annex to 13/CMP.1, paragraphs 44 to 48 inclusive. http://www.environment-agency.gov.uk/business/topics/pollution/137208.aspx This site provides details of what is classified as confidential under the Registry regulations.
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	The new internet address of the United Kingdom Registry is: https://ets-registry.webgate.ec.europa.eu/euregistry/GB/index.xhtml

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	The overall change to a Consolidated System of EU Registries also triggered changes to data integrity measures, as reflected in the updated **disaster recovery plan.** The complete description of the consolidated registry was provided in the common readiness documentation and specific readiness documentation for the national registry of EU and all consolidating national registries. The documentation is annexed to this submission.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	On 2 October 2012 a new software release (called V4) including functionalities enabling the auctioning of phase 3 and aviation allowances, a new EU ETS account type (trading account) and a trusted account list went into Production. The trusted account list adds to the set of security measures available in the CSEUR. This measure prevents any transfer from a holding account to an account that is not trusted.
The previous Annual Review recommendations	There were no recommendations proposed in IAR/2011-GBR/2/1 in the Summary of Findings.

15 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

15.1 GENERAL OVERVIEW

The UK believes that a comprehensive and global post-2012 regime with broad coverage of sectors offers the best option to address the issue of response measures. Response measures is not a stand-alone issue and has strong links to technology and capacity building.

Both positive and negative effects must be taken into account. A global transition to a low carbon economy will provide parties with social, economic and sustainable development opportunities, but we acknowlegde that it should address vulnerabilities. We need to ensure that transition to a low carbon economy supports sustainable development processes in all countries, and that effort to assess potential effects of such response measures does not constrain efforts to develop and implement ambitious policies and measures to mitigate climate change.

There is a need for better evidence based information exchange in order to get a better understanding of the actual impacts felt, recognising the need to strengthen and support capacities to compile, analyse and use socio-economic data in assessing potential spill-over effects/response measures.

The UK continues to pursue initiatives that have been mentioned in previous inventory reports and national communications, such as considering food miles, sustainability of the EU Common Agricultural Policy and Trade for Aid. This chapter is not an exhaustive list but instead outlines recent examples of what the UK is doing to understand impacts of response measures on developing countries and actions it is taking to minimize adverse impacts.

15.2 UNDERSTANDING IMPACTS OF RESPONSE MEASURES

Understanding the impacts of response measures is a key step to be able to minimize the adverse impacts. The UK continues to undertake assessments, reviews and analysis projects to better understand the impacts its policies could have on developing countries, and how they could be addressed. Consequently, the UK takes these findings and seeks to apply them in UK and within the EU community in order to minimize adverse impacts in accordance with article 3, paragraph 14. Recent examples of areas where ongoing research and action is taking place are outlined below.

15.2.1 UK research, reports and analysis

The UK has undertaken research to determine the extent of impacts of response measures and uses this information to implement policies in a way that takes into account the impacts

of response measures on all developing countries. Examples of areas where research is ongoing are transport biofuels and indirect emissions.

The UK Department of Transport has and continues to lead work into understanding Indirect Land Use Change (ILUC) impacts from biofuels. Examples include:

- A study in 2011 which considered the potential for regional (i.e. sub-national, national and supranational) approaches to avoid ILUC from biofuels production. This work highlighted potential actions that may reduce ILUC, and assessed the potential to measure and monitor any such regional level actions to avoid ILUC[49].

The UK Department for the Environment, Food and Rural affairs has funded and continues to fund research looking at embedded emissions and sustainable production and consumption, in particular:

- The development of an embedded carbon emissions indicator. The aim of this project is to monitor greenhouse gas emissions associated with UK consumption, including those relating to trade flows. This work will provide a high level analysis of the UK national "carbon footprint", and in particular will assess the emissions which are embedded in products which the UK imports and exports[50].

  This year's output from the monitoring, which is published in the Official Statistics Release, can be found online[51].

15.2.2 Within the EU Community

The UK is an active participant within the EU community and we continue to minimize the adverse effect of our policies and measures through activities such as:

- The EU Emissions Trading System (EU ETS) is the EU's main policy mechanism for reducing CO_2 emissions from energy intensive sectors. Through the EU ETS and the linking directive, which allows European participants in the EU ETS to engage in the CDM as a way of meeting their commitments, the EU has increased investments in renewable energy and energy efficiency in developing countries making an important contribution to diversifying the energy mix in those countries.
- Aviation has been included in the EU ETS from 1 January 2012, the most significant expansion of the scope of the System since its inception. We estimate that the inclusion of aviation in the EU ETS will result in emission reductions across the EU of 476 $MtCO_2$ cumulatively for the period 2012-2020.
- A Greenhouse Gas Effort Sharing Decision sets targets for emissions reductions or growth limits in those sectors of Member States' economies not covered by the EU ETS (excluding Land Use, Land Use Change and Forestry). For the UK, the target to reduce emissions in the non-ETS is 16 per cent below 2005 levels by 2020. For the EU as whole, the reduction target is approximately 10 per cent. The Decision promotes domestic action and limits the use of international project credits, such as the Clean Development Mechanism (CDM), to meet targets. They are limited (annually) to 3% of Member States' 2005 emissions in the non-ETS.

[49] http://www.dft.gov.uk/publications/regional-level-actions-to-avoid-iluc
[50] http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&ProjectID=17729&FromSearch=Y&Publisher=1&SearchText=emissions&GridPage=7&SortString=ProjectCode&SortOrder=Asc&Paging=10#Description
[51] http://www.defra.gov.uk/statistics/environment/green-economy/scptb01-ems/

- A Renewables Directive sets targets for each member state for the proportion of renewable energy generation by 2020. The EU has a 20% renewables target by 2020. The UK's legally binding target is 15%. The Renewables Directive also set every Member State a target of supplying 10% of transport fuel from renewable sources by 2020.
- The Directive on the geological storage of CO_2 outlines a regulatory framework for the safe capture, transport and storage of carbon dioxide in the EU. Up to 300 million allowances from the new entrants reserve of the EU ETS will be used to support the demonstration of carbon capture and storage (CCS) and innovative renewable technologies. The UK's action on CCS are expanded in the sections below.

Further information can be found in the 1990-2009 EU inventory report.

15.3 ACTIONS TO MINIMIZE ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14

The UK Government is committed to achieving an ambitious, effective and equitable global deal which will limit global temperature rise to 2°C, and to helping countries adapt to the inevitable impacts of climate change. The transition to a low carbon world requires support to developing countries in their domestic efforts to mitigate and adapt to climate change and to develop their own low carbon economies.

The UK has taken action to minimize adverse impacts in accordance with article 3, paragraph 14 through fast start finance. Additionally, the UK's International Climate Fund (ICF) will provide £2.9bn of climate finance from 2011 to 2015. This funding will be focused on helping the poorest people adapt to the effects of climate change, helping to encourage low carbon development, and protecting the world's forests and the livelihoods of the people who depend on them.

15.3.1 The International Climate Fund

The ICF is intended to demonstrate that building low carbon, climate resilient growth at scale is feasible and desirable. Additionally, it is intended to support climate negotiations, particularly through providing support for adaptation in poor countries and building an effective international architecture. The fund also aims to recognise that climate change offers real opportunities to drive innovation and new ideas for action, and create new partnerships with the private sector to support low carbon climate resilient growth. Detailed information on the fund, including on the projects that it is supporting, can be found on our website[52]. Some examples of the types of projects that are supported by the fund follow.
The UK is investing £130 million in the Climate Public Private Partnership (CP3) from the ICF. CP3 will support projects delivering renewable and efficient energy, new technology and protect natural resources in emerging and developing countries including Africa and Asia. The funds will be run on a strict commercial basis by professional fund managers, demonstrating that developing country climate projects offer real investor opportunities. By investing in new renewable installations and technologies the initiative is expected to contribute to deploying approximately 7,000 Megawatts of clean, reliable energy and create

[52] https://www.gov.uk/government/policies/taking-international-action-to-mitigate-climate-change/supporting-pages/international-climate-fund-icf

up to 40,000 jobs. Across a range of investments CP3 is expected to contribute to GHG emission savings of at least 265 million tonnes of CO2 over the lifetime of the projects in which CP3 funds are invested.

ICF funds of £98million over 2012 to 2015 will support the Green Africa Power (GAP) project, to tackle specific constraints to private sector investment in renewable power generation in Africa. The UK will provide £95 million to capitalise GAP - a new company that will be established under the Private Infrastructure Development Group (PIDG) Trust. GAP will invest in renewable energy projects to demonstrate the viability of renewable energy in Africa so that future projects are more likely to happen and attract private developers and investors. A further £3 million will be used to set up the project, monitor and evaluate these impacts and capture and disseminate this knowledge. GAP aims to support projects that will install ~270MW of renewable energy in Africa in 4 years, avoiding an estimated 2.3m tonnes of CO2 emissions.

A £15m grant will support the growth of silvopastoral systems (SPS) in Colombia to reduce greenhouse gas emissions, improve the livelihood of farmers, protect local forests and increase biodiversity. Agriculture is one of the biggest sources of greenhouse gas emissions in Colombia and many other developing countries, and a key driver of deforestation. Addressing this fact, the UK and partners are working with cattle ranchers to improve degraded grazing land by using SPS. This means managing the land in a different way: planting trees, shrubs, fodder crops and living fences and conserving existing forest. Participating small farmers, the majority of whom are living in conditions of rural poverty, are able to raise more, healthier cattle on their existing land using SPS, increasing their income and reducing the need to clear forest. This project aims to convert 28,000 hectares of grazing land to SPS, saving around 2MtCO2e over the next 8 years, and create a strategy for increasing the use of SPS in Colombia and beyond.

Through the ICF, the UK is also providing £6m to help kick start solar energy projects in India. This funding will offset part of the financing cost of using ADB political and commercial risk guarantees on commercial loans for small-scale (2-25 MW) solar plants. These guarantees on private sector loans are available under ADB's Solar Power Generation Guarantee Facility. This will help India make the shift to a low carbon economy, and will reduce the risks for investors, generating an estimated £265m in private sector investment. This should lead to around 130 MW of solar power capacity, avoiding 4.9 million tonnes of carbon dioxide going into the atmosphere over the next 25 years.

The UK has also contributed £7m and technical support to the World Bank's Partnership for Market Readiness to help developing countries design market-based mechanisms for reducing their greenhouse gas emissions. This will foster increased investment in green technologies across the world and help stimulate private sector low carbon investment opportunities. The Partnership aims to increase the number of experts in 16 developing countries to design and implement market-based schemes, and create a knowledge sharing forum.

Low carbon technology needs to be accessible to all and the UK will promote growth and prosperity by stimulating investment in clean energy, and increasing energy access for the poor. Through our ICF funding to the Scaling up Renewable Energy Program (SREP), we will help to support 3.4 million people in securing access to clean energy including in Ethiopia, Honduras, Kenya, Mali and Nepal. For example, in Kenya, SREP investment in increased renewable energy services will facilitate the construction of a geothermal plant and

enable this to be connected to the grid to increase Kenya's renewable energy supply by 32%. In addition, by connecting this 200MW power plant to the grid by 2015, it will demonstrate a model for replication to enable a potential 5000MW to be generated by geothermal power in Kenya by 2030.

The UK has committed up to £60 million of finance from the ICF to support developing countries to develop both the technical and institutional knowledge necessary to enable the deployment of CCS technologies. The UK has agreed to fund £35m and £25m respectively to Asian Development Bank and World Bank Trust Funds to support CCS capacity building projects. Financial support would be channelled toward a range of projects in China, South Africa and Indonesia with the aim of ensuring sufficient political support is created to pave the way for full scale demonstration and ultimately the deployment of CCS.

The Nationally Appropriate Mitigation Actions (NAMA) Facility was launched by the UK and German governments in December 2012. The UK has committed £25 million (approximately €30 million) to the NAMA Facility with Germany committing another €40 million. The Facility will fund the most transformational parts of NAMA plans. NAMAs are concrete projects, policies, or programmes that shift a technology or sector in a country onto a low-carbon development trajectory. This project will focus on those parts of the projects that are stretching and aspirational, that are pushing to do much more than business as usual to mitigate the impacts of climate change.

15.3.2 Knowledge transfer

Knowledge transfer can help accelerate the development and deployment of low-carbon and climate resilient technologies to help developing countries mitigate and adapt to climate change.

The UK cooperates in the development, diffusion and transfer of less greenhouse-gas emitting advanced fossil-fuel technologies, and/or technologies relating to fossil fuels that capture and store greenhouse gases, and encouraging their wider use. The UK supports the establishment of a Technology Mechanism (TM), as agreed at COP16 in Cancun 2010, and is already involved with several knowledge transfer initiatives. In addition to the UK's long standing involvement in initiatives such as the Climate Technology Initiative recent actions in this area include:

- In 2010 the UK established the Climate and Development Knowledge Network (CDKN) to provide developing countries access to the latest research, knowledge, technical assistance and capacity building on climate change. In response to requests from developing countries themselves, CDKN helps policy-makers and practitioners plan and implement strategies that meet the climate challenges of their country.
- The UK has been supporting the concept of Climate Innovation Centres (CICs) in developing countries. These centres will provide a national focal point for innovation in climate-friendly technologies, providing business development support; R&D grants and links to local universities; links to local financiers; and market analysis within that country. CICs will be linked to other CICs by InfoDev (the implementing partner) to encourage cross-border learning and knowledge sharing. The first centre has opened in Kenya in September 2012, with Ethiopia closely following. Scoping work is also underway in other countries.

15.3.3 Research collaboration

Enhancing global collaboration on research, development and demonstration (RD&D) will be essential to ensure innovation and take-up of climate technologies in developing countries. The UK is cooperating in the technological development of non-energy uses of fossil fuels, and doing so in partnership and supporting developing countries. We are exploring opportunities to support RD&D 'gap-filling' activity on climate technologies (both for mitigation/low carbon development and adaptation activities).

Recent examples of this commitment to collaborative research are 2010-2011 projects on low carbon technology transfer to China and India that the Department of Energy and Climate Change has supports. The main focus of the studies is to provide new empirical evidence to low carbon innovation in developing countries to inform international policy development. Both studies feature a range of low carbon technologies and examine the factors that influence innovation and technology transfer, including technological capacity, access to intellectual property rights and the role of policy frameworks.

International engagement is a significant part of the AVOIDing dangerous climate change (AVOID) programme and there have been a number of international activities to build links and explore understanding of the issues. The programme has investigated China's technology options for reducing CO_2 emissions from the energy sector in order to meet a national 2050 emissions target that is consistent with the international goal of limiting global temperature rise to below 2°C. The initial findings of the project were reviewed by Chinese researchers who subsequently provided input to the final report. The final report was followed by a workshop in Beijing involving UK and Chinese researcher and officials to share and compare thoughts on potential technology pathways for China. The AVOID programme is also currently considering options for working with Indian research institutes to conduct a similar analysis on India's technology options for meeting the 2°C target.

The UK has recently signed a Memorandum of Understanding (MoU) on energy research with the government of Bangladesh. Under the MoU, collaborative research projects on renewable energy as well as research related to energy technologies, systems, services and policies will be developed. It will involve UK universities and institutes partnering with colleagues in Bangladesh.

The UK is playing a key role on promoting knowledge sharing and capacity building in developing countries on Carbon Capture & Storage (CCS). The UK has committed up to £60 million of finance from the International Climate Fund (ICF) to support developing countries to develop both the technical and institutional knowledge necessary to enable the deployment of CCS technologies. The UK continues to jointly lead with Australia the CCUS initiative under the Clean Energy Ministerial, the next meeting of which will be held in Delhi in April 2013 involving governments of both developed and developing nations. The UK is active in a number of multilateral organisations such as the Carbon Sequestration Leadership Forum (CSLF) which aims to promote the deployment of CCS worldwide in both developed and developing countries. In addition, in March 2013 the UK will co-host the third 4 Kingdoms Initiative workshop with the government of Norway, which brings together representatives of four oil-producing countries to drive efforts to reduce the economic losses of CCS through alternative uses for CO_2.

15.3.4 Capacity Building projects on Renewable Energy & Energy Efficiency

The UK is cooperating in the development, diffusion and transfer of less greenhouse-gas emitting advanced fossil-fuel technologies, and/or technologies relating to fossil fuels that capture and store greenhouse gases, and encouraging their wider use; and through capacity building projects is facilitating the participation of the least developed countries.

The UK is supporting the development of low carbon technology and the increased use of renewable energy to ensure that developing countries can move to a low carbon future that supports economic growth. The UK is a signatory to the International Renewable Energy Agency (IRENA) which is an intergovernmental treaty organisation set up in 2009 to promote a rapid transition to the widespread and sustainable use of renewable energy technologies internationally. The UK has been playing an active part in IRENA by chairing its Policy and Strategy Committee to help develop the agency's work programme for 2012 (which includes activities on Policy Advisory Services and Capacity Building) and its mid-term strategy. Similarly, the UK (both DFID and DECC) continues to contribute to the Clean Technology Fund (CTF), one of the Climate Investment Funds; at the Durban COP in 2011, the UK announced a further contribution of £150m to the CTF, in addition to £385 already provided (2008-2011).

It is important to tackle both the supply and the demand side to achieve sustainable low carbon energy. In the 5th National Communication the UK illustrated its continued involvement with multi-lateral partnerships such as the Renewable Energy and Energy Efficiency Partnership, which has the objective of accelerating the deployment of renewable energy and energy efficiency technologies in developing countries as a means of reducing carbon emissions, increasing energy security, and improving access to sustainable energy. It does so primarily through funding small scale capacity building projects, and to date it has funded 150 projects. The UK has also been recently active in energy efficiency capacity building, such as:

- The UK is working within the International Partnership for Energy Efficiency Co-operation (IPEEC) with key developed and developing countries to share experience and learn from each other's policy successes and failures, and identify opportunities for collaborative work to address issues of mutual interest or concern, where such international action can add value to domestic efforts/expertise. A work programme has been developed encompassing a range of activities covering appliance standards and labels, sustainable buildings, financing mechanisms, data collection and indicators, energy management, the role of utilities (UK_led) and capacity building activities.

15.3.5 Capacity building projects on adapting to climate change

The UK Government is working to ensure that aid addresses both the causes and likely effects of climate change so that current and future progress in tackling poverty continues. The world's poorest people are hit hardest by the impacts of climate change with their crops lost to floods and drought, their homes damaged by floods and threatened by rising sea levels, and lives lost to extreme weather events. They are the most vulnerable and least able to adapt.

The UK is supporting developing countries to adapt to climate change through practical on-the-ground support, by building climate knowledge and capacity in vulnerable countries and by helping to ensure countries get access to sufficient finance.
Examples include:

- Since Durban the UK has committed £100m from DFID and DECC to the Pilot Programme for Climate Resilience (PPCR) in addition to the UK's earlier £225m contribution. This support is designed to deliver transformational outcomes in a small number of pilot countries through supporting the integration of climate resilience into development planning and budgeting.
- The UK also announced £10m support from DFID for the Adaptation Fund to support concrete adaptation activities that reduce vulnerability and increase adaptive capacity to respond to the impacts of climate change, including variability at local and national levels.

15.3.6 Energy Market Reforms – responding to energy market imperfections

Energy Market Reform (EMR) is the biggest change to the UK electricity market since privatisation. Although the current market has been effective, a number of unprecedented challenges require us to transform the UK's electricity sector. It is expected that a fifth of our current capacity is due to close over the next decade and the amount of intermittent and less flexible generation will increase. In addition, there are ambitious climate and renewable targets that we need to meet.

The UK Government's vision is for low-carbon generation to compete fairly on cost and EMR is a set of arrangements that will take the UK through this transition. We will continue to work with the existing market whilst maintaining a liberal approach to addressing the market failures.

In July 2011 the UK Government published the EMR White Paper ("*Planning our electric future: a White Paper for secure, affordable and low-carbon electricity*")[53] which set out a package of electricity market reforms:

- the form of the low-carbon contracts (Feed-in-Tariff with Contracts for Difference (FiT CfD)) to bring forward all forms of low-carbon electricity generation;
- how we will transition from the current Renewables Obligation to the FiT CfD;
- a Carbon Price Floor to put a fair price on carbon; and
- an Emissions Performance Standard to provide a regulatory backstop on the amount of emissions new fossil fuel plants can emit.

The White Paper marked the first stage of the market reform process and was followed by the publication of the Technical Update[54] to the White Paper in December 2011 which completed the strategic framework outlined in the White Paper.

The Technical Update provides further details on the institutional framework for delivery of the reforms; the form of Capacity Mechanism we will legislate for to ensure security of

[53] http://www.decc.gov.uk/en/content/cms/legislation/white_papers/emr_wp_2011/emr_wp_2011.aspx
[54] http://www.decc.gov.uk/en/content/cms/legislation/white_papers/emr_wp_2011/tech_update/tech_update.aspx

supply; and the next steps in the EMR process. It sets out the Government's view that the System Operator – National Grid – is best placed to deliver both the FiT CfD and the Capacity Mechanism.

16 Other information

There is no additional information to include in this chapter.

17 References

References for the main chapters and the annexes are listed here and are organised by chapter and annex. During 2008 the BERR energy team and the Defra climate teams formed the Department of Energy and Climate Change (DECC), references in this document refer to correct name at the time of original publication.

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18 Acknowledgements

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Table 18-1 Contributors to this National Inventory Report and the CRF

Person	Technical work area and responsibility
Main authors	
Broomfield, Mark	Sector expert for solid waste disposal on land
Cardenas, Laura[55]	Sector expert for agriculture; author of all sections on agriculture. Compilation of Sector 4 of the CRF.
MacCarthy, Joanna	Project Manager for the UK Greenhouse Gas Inventory with overall responsibility for the NIR and the CRF[56]. Author of Annex 1, Annex, 5, Annex 7, and sections related to fluorinated gases and uncertainties
Murrells, Tim	NAEI transport manager. Contributing author to all sections on transport.
Pang, Yvonne	Approach 1 (error propagation) uncertainty analysis. Responsible for road transport data compilation. Project manager for the air quality inventory, assistance with inventory QA/QC
Passant, Neil	Author of selected sections on energy and industry; contributions to most chapters. Developments to the methods used to estimate GHG emissions from the non-energy use of fuels and stored carbon. Co-author of Annex 9.
Thistlethwaite, Glen	Compilation of emission estimates, in particular the offshore sector and cement. Main author of chapters and annexes for 1B, co-author of sections relating to waste water treatment, EU ETS, and information about inventory improvements, stakeholder consultation, and the reference approach
Thomson, Amanda[57]	Author of all sections on Land Use Change and Forestry. Compilation of Sector 5 of the CRF.
Webb, Nicola	Report manager. Author of Chapter 1 and 10, the Executive Summary, and Annexes 10 and 11. Contributor to all sections on recalculations, author of sector overviews in all chapters. Co-author of chapter 2.
Contributors	
Champion, Helen[58]	Review of draft NIR and contributions regarding National Inventory System. Author of Chapter 15
Gilhespy, Sarah[1]	Contributions to agriculture inventory compilation and text
Goodwin, Justin[59]	Contribution to text on QA/QC plan

[55] Rothamsted Research

[56] The UK greenhouse gas inventory is part of the UK National Atmospheric Emissions Inventory contract. The UK National Atmospheric Emissions Inventory is funded by the UK Department for Environment, Food & Rural Affairs and the Department of Energy and Climate Change and is contracted to a consortium led by Ricardo-AEA.

[57] Centre for Ecology and Hydrology

[58] Climate, Energy, Science and Analysis, Department for Energy and Climate Change

[59] Aether

Person	Technical work area and responsibility
Hallsworth, Stephen[3]	Responsible for compiling the CRF for LULUCF
Hobson, Melanie[5]	Compilation of rail emissions estimates and text for this sector
Manning, Alistair[60]	Verification of the UK greenhouse gas inventory (Annex 10).
Martinez, Carlos	Co-author of Chapter 2
Matthews, Robert[61]	Contributions to LULUCF inventory
Misselbrook, Tom[1]	Contributions to agriculture inventory compilation and text
Salisbury, Emma[5]	Responsible for compilation of emission estimates for the OTs and CDs, and report text relating to this
Venfield, Helen	Responsible for sections on shipping and inland waterways
Walker, Charles	Sector expert for aviation in the NAEI.
Watterson, John	Knowledge leader responsible for the review of this report
Yamulki, Sirwan[3]	Contributions to LULUCF inventory (forestry drainage)
Additional assistance	
Aston, Clare	Data acquisition, report printing
National Inventory Steering Committee	Suggestions and improvements to draft versions of the NIR

Table 18-2 Key Data Providers to the Greenhouse Gas Inventory

Company
UKPIA
UK Oil and Gas
Environment Agency
DECC
Defra
Mineral Products Association
UK Gas Distribution Networks
Tata Steel
DfT
NIEA
SEPA

[60] The Met Office
[61] Forest Research